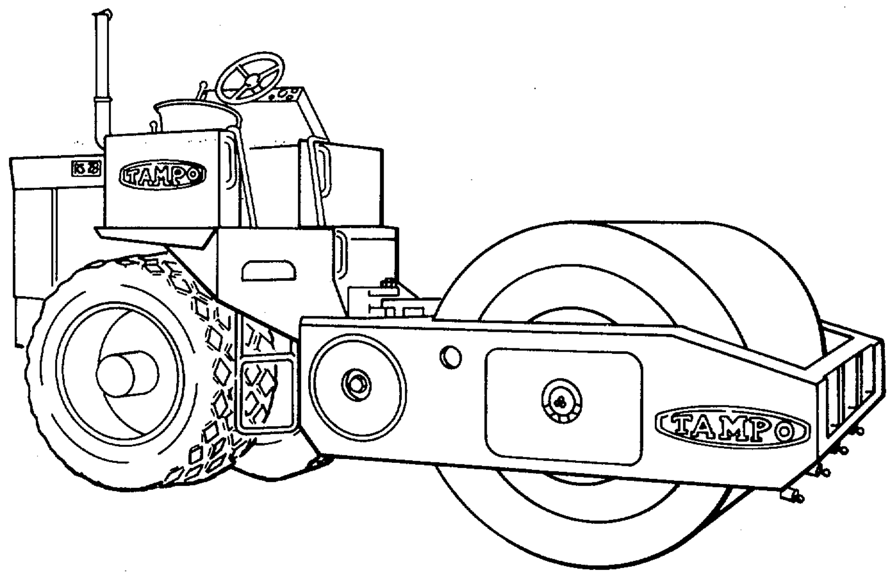
TECHNICAL MANUAL
OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT
AND GENERAL SUPPORT MAINTENANCE MANUAL

FOR

ROLLER, VIBRATORY, SELF-PROPELLED, HIGH IMPACT, SINGLE SMOOTH DRUM (CCE) TAMPO MODEL RSu28

(NSN 38950 101 2u8875)



HEADQUARTERS, DEPARTMENT OF THE ARMY

4 FEBRUARY 1985

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HIGH IMPACT, SINGLE SMOOTH DRUM
(CCE) TAMPO MODEL RS-28
NSN 3895-01-012-8875

WARNING

Consider hazards of job and wear protective gear such as safety glasses, safety shoes, hard hat, etc. to provide adequate protection.

WARNING

When lifting engine, make sure lifting device is fastened securely. Be sure item to be lifted does not exceed the capacity of the lifting device.

Be sure the engine is securely mounted to overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

Hold the flywheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft, when removing the attaching bolts. The flywheel is not doweled to the crankshaft.

When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys, and belts. Do not make contact across battery terminals. It results in severe arching.

Explosive hydrogen gas may remain in and around the battery for several hours after it has been changed. Sparks and flame can ignite this gas.

Loss of shutdown control could result in a runaway engine and can cause personal injury.

WARNING

Always use caution when using power tools.

WARNING

Use caution when welding on or near the fuel tank. Explosion can result if heat build-up inside the tank is sufficient.

When using compressed air to clean a component such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.

When making an oil cooler core pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose, or the oil cooler core.

Use extreme care while removing coolant pressure control cap. Remove the cap slowly after the engine has cooled. Sudden release of pressure from a heated cooling system can result in scalding from the hot liquid.

Avoid excessive injection of ether into engine during start attempts. Follow instructions on container or by the starting aid manufacturer.

WARNING

Do not use carbon tetrachloride as a cleaning agent because of harmful vapors it releases. Use perchloroethylene or trichloroethylene. While less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated. Use protective gloves, and goggles or face shield and apron.

Circulating a solution of trichloroethylene through an oil cooler for cleaning shall be done in well-ventilated area.

Exercise caution when using oxalic acid to clean the cooling passages of the engine.

Fuel spray from an injector can penetrate skin. Fuel oil which enters the bloodstream can cause serious infection. Follow instructions and use proper equipment to test an injector.

Do not inhale alkali cleaners. Skin rashes can be caused by alkali's.

Use extreme care in handling using butyl cellosalve to clean a lubrication system. Serious injury or damage to surfaces could be caused by splashing. Immediately wash off spilled fluid with clean water.

TECHNICAL MANUAL
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HEADQUARTERS
DEPARTMENT OF THE ARMY
WASHINGTON, DC, *4 February 1985*

OPERATOR'S, ORGANIZATIONAL, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL FOR ROLLER, VIBRATORY, SELF-PROPELLED, HIGH IMPACT, SINGLE SMOOTH DRUM (CCE) TAMPO MODEL RS-28 (NSN 3895-01-012-8875)

REPORTING OF ERRORS AND RECOMMENDING CHANGES

You can help improve this publication. If you find any mistakes, or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publication and Blank Forms), or DA Form 2028-2 located in the back of this publication direct to: US Army Tank-Automotive Command, ATTN: AMSTA-MB, Warren, MI 48090. A reply will be furnished to you.

This technical manual is an authentication of the manufacturer's commercial literature and does not conform with the format and content specified in AR 310-3, Military Publications. This technical manual does, however, contain available information that is essential to the operation and maintenance of the equipment.

NOTE

To locate information on operation, maintenance or repair of specific components, refer to the index, page 657.

Page

CHAPTER I

INTRODUCTION

COMPONENT IDENTIFICATION

NOTE

When practical, always refer to identification tags and plates to determine part identity.

ENGINE

Detroit Diesel 453 Number 5043-7201 20-3010 Motor

NOTE

The engine serial number from the identification plate is needed to determine the use of some parts.

TRANSMISSION

Funk Double Pump Drive designated T20-0063 by Tampo

HYDROSTATIC DRIVE

Sundstrand Model 20-2055 Pump, Model 22-3037 Motor

VIBRATORY DRIVE

Sundstrand Model 20-2022 Pump, Model 20-3010 Motor

DRIVE AXLE

Rockwell SA2410 designated VRH 180 by Tampo

POWER STEERING

Sperry-Vickers VTM Series Char-Lynn Orbitrol Control

WARRANTIES

Tampo Warranty One (1) year from date of delivery to the first user. Tampo's obligation is to repair or replace, F.O.B. its factory, any part of its own manufacture that proves defective in material and workmanship. Those items purchased for use on a Tampo roller are covered under the respective manufacturer's warranty as follows:

Engine Detroit Diesel: One (1) year or 4000 hours, whichever occurs first. First six (6) months or 2000 hours, free parts and labor. Second six (6) months or 2000 hours, free parts and fifty (50%) percent labor. For parts and service, contact nearest Detroit Diesel engine dealer.

Sundstrand Pumps and Motors: The Sundstrand hydraulic components are warranted for a period of two (2) years from date of delivery. This warranty covers repairs or replacement of parts only. Labor and other charges are not covered under this warranty. Certain repairs are allowed without voiding this warranty. These repairs are described in the Sundstrand Bulletin #9630, Section VII. Further details and procedures on warranty repair are also listed under Section VII in Bulletin #9630.

Goodyear Tires: Warranty against defects in material and workmanship will be made on a prorated basis of tire wear. These claims are made with the nearest local representative of Goodyear Tire and Rubber Company.

Reliable Battery: Warranty period is two (2) years from date of delivery on a prorated basis. Warranty claims should be made to the nearest member organization of the Independent Battery Association or to Tampo Manufacturing Company.

Funk Manufacturing Company: Warranty of transmission, clutch, and pump drive gearbox is six (6) months from date of delivery. Warranty claims received by Tampo Manufacturing Company will be processed and forwarded to the manufacturer for consideration.

Rockwell International: The axles and differentials used on rollers carry an overall warranty of one (1) year from the date of delivery against defective material or workmanship but not against damage caused by accident or abuse. Rockwell, at their option, will repair or replace such parts if found on examination to be defective. Requests for warranty may be made direct with Rockwell International or forwarded to Tampo Manufacturing Company for processing and submission to the manufacturer.

Sperry-Vickers Power Steering Pumps: The manufacturers warranty is ninety (90) days from the date of delivery. Requests for warranty repair will be processed by Tampo Manufacturing Company and forwarded to the manufacturer for consideration.

Char-Lynn Orbitrol and Column: These components carry a ninety (90) day warranty starting with the date of delivery. Warranty claims will be processed by Tampo Manufacturing Company and forwarded to the manufacturer for consideration.

Hayden Oil Cooler: This component carries a twelve (12) month warranty. Claims made during the warranty period will be processed by Tampo Manufacturing Company and forwarded to the manufacturer for consideration.

Date of Delivery The date the Tampo Roller is received by the purchasing agency.

WARRANTIES (Continued)

Venders warranty covers parts, unless otherwise specified. Warranty on any component is voided for any failure caused by physical accident, abuse, lack of proper maintenance, contaminated hydraulic systems, etc.

SPECIFICATIONS

RS-28

Weight	19,450 pounds
Rolling Width	84 inches
Roll Diameter	60 inches
Overall Width	96 inches
Overall Height	98 inches
Overall Length	17 feet, 3.5 inches
Wheel Base	108.5 inches
Turning Radius	17 feet, 10 inches
Tire Size, Standard	23.1/18-26 all weather high flotation tread.
Vibration Frequency	1100-1500 vpm
Centrifugal Force	30,000 pounds maximum
Speed, Forward and Reverse	0-15 mph
Power Unit	Detroit Diesel 4-53, 107 HP at 2,200, with double pump drive and disconnect clutch.
Roller Drive	Variable speed hydrostatic drive with heavy-duty transmission and planetary axle with high-traction differential.
Vibratory Drive	Variable speed hydrostatic independent of roller travel speed.
Steering	Automotive hydraulic power type with center-hinge body pivot (articulated) steering.
Brakes	Hydrostatic braking in drive train. Hydraulic brakes on drive axle. Parking brake on transmission output shaft.
Fuel Capacity	50 gallons
Oil Reservoir Capacity	16 gallons

GENERAL INFORMATION

This is a Department of the Army authenticated operation and maintenance manual for the Tampo RS-28 Vibratory Roller, NSN 3895-01-012-8875. As such, this document complies with MIL-M-7298C in content and format.

The vibratory roller is used in construction operations such as road bed repairs and construction. Primary tasks are compacting new beds of sand and gravel prior to laying an asphalt surface. Secondary uses are compaction of pavement base courses and stabilizing bases.

Compaction is accomplished by a single smooth drum roller powered by a vibratory drive capable of producing between 1100 and 1500 vibrations per minute. The vibratory drive and drive train are each powered by a hydrostatic pump and motor unit, coupled by a double pump drive transmission to a Detroit Diesel four-cylinder 4-53 engine. Hydrostatic pumps and motors are manufactured by Sundstrand. The double pump drive transmission is manufactured by Funk.

Steering is hydrostatically assisted by a Sperry-Vickers pump and an Orbitrol control. It is accomplished through an articulated hinged joint behind the roller drum. Power is transmitted to drive wheels through a Rockwell planetary drive axle.

Braking is accomplished by shutting off the hydrostatic drive under normal conditions, and through Rockwell hydraulic brakes under emergency conditions.

Maintenance Forms and Records

The roller is manufactured by Tampo Manufacturing Company of San Antonio, TX. Warranties on all components of the equipment are handled by Tampo. Maintenance Forms and Records

Maintenance forms and records on this equipment are to be maintained in accordance with standards established in the current TM 38-750, The Army Maintenance Management System (TAMMS).

Equipment Improvement Recommendations (EIR)

Prepare recommendations on equipment improvement in accordance with TM 38-750. ASF 368, Quality Deficiency Report should be prepared and mailed to: Commander, US Army Tank-Automotive Command, Warren, MI 48090.

Shipment and Storage

Refer to TB 740-97-2 for procedures covering preservation of equipment for shipment and storage. Refer to TM 74090-1 for instructions on administrative storage.

Destruction to Prevent Enemy Use

Refer to TM 750-244-3 for procedures covering destruction to prevent enemy use.

Fire Protection

A hand-operated fire extinguisher may be installed at the discretion of the using unit. Approved hand-portable fire extinguishers are listed in TB 5-4200-200-10.

Safety Precautions

Always observe the following precautions to prevent injury or damage to equipment:
- Use trained operators only.

Always use slower speeds and added caution when operating close to a lift edge or traveling downhill.
Never travel across a slope; always travel up or down a slope.

- Always engage the parking brake before dismounting the unit.

- Never shut down the engine when traveling up or down a slope. Always move the forward-reverse lever to the neutral position to slow the unit.

CHAPTER II

OPERATIONS

THEORY OF OPERATION

Compaction is the compression of soil by forcing air and water from between its particles. This can be accomplished in many ways, but in the case of sand and gravel (the two materials most often used as the subbases in paving), the best way is through vibration. The Tampo roller can produce as much as 30,000 pounds of impact force up to 1500 times a minute over a path 60 inches wide. The amount of compaction obtained by the machine is not a result of the number of blows it strikes, but of the number at which the roller and soil vibrate in union.

All types of soil can be moved to a state known as resonance under vibration. In this state, particles in soil, particularly sand and gravel, will compact 10 to 50 times more efficiently than when under random impacts or pressure.

Where time and conditions allow it, some research should be done to determine the resonance of the material being compacted. However, even when this research cannot be done, vibration in any form will shake sand and gravel into a more compact base than without vibration.

In addition, compaction can be enhanced by the moisture content of the soil. Particles float into a compact condition when moisture reaches an optimum condition best determined by engineering studies. But if the moisture content goes beyond the optimum point for compaction, the force of impact is spread over too great an area, destroying the compactive force.

A vibratory roller can produce compaction up to a depth equal to three times the width of the roller if soil and moisture conditions are ideal and resonance can be obtained. Even under this condition, the top inch of soil will remain loose. Final compaction of this material can be attained by rolling the material without the vibrator engaged.

The vibratory roller is best used on sand and gravel and is least efficient on loam or clay soils. Loam and clay not only bear weight through friction among particles, but also through electrical attraction among the particles and suction from moisture in the soil. Vibration cannot efficiently break down those forces. When clay or loam is encountered while making a subbase, consideration should be given to changing equipment (a determination best made by the field engineer).

SAFETY

Read this manual completely before operating roller. Make sure you understand and follow these instructions thoroughly.

Carefully inspect your equipment for visual defects: leaks in fuel, lubrication and hydraulic systems, and broken or missing parts.

DO NOT START OR OPERATE A DEFECTIVE MACHINE. Have it repaired and then okayed by your supervisor before using it.

Always enter operator's platform from the right-hand side of tractor utilizing ladder and safety grab rails.

Be sure to clean any oil, grease, or mud accumulation from floor of operators platform, stepping points, and grab rails to minimize the danger of slipping.

Do not climb off the machine with engine running. After applying parking brake, pull out fuel cutoff stop and turn off key.

Never leave the roller unattended with the engine running as unauthorized personnel may accidentally engage controls and move machine resulting in possible serious injury.

Never stand up or climb on or off machine while in motion.

DO NOT STAND BETWEEN TRACTOR AND ROLL FRAME with engine running or when steering roller. This is an articulated machine and there is danger of being crushed between the two units.

Always stop machine, turn off engine, and set parking brake to lubricate or make minor adjustments.

PREPARING THE ROLLER FOR OPERATION

All rollers are completely serviced and properly lubricated before leaving the factory, but always check all liquid levels to ensure against damage or inadvertent leaks during shipment.

Check ignition wiring connections, battery connections, and battery water level.

Fill fuel tank with a good grade of clean diesel fuel.

Check all fuel lines for leaks.

Check hydraulic reservoir for proper oil level on sight gage.

The roller is now ready to operate. The engine is factory tested.

TO START ENGINE

NOTE

See page 12 if roller engine has never been started before.

Always enter operator's platform using ladder and safety grab rails provided.

Sit securely - do not operate this machine from any position other than seat provided.

Before attempting to start engine, be sure that all personnel are clear from machine.

Check to see that parking brake is on.

Be sure vibratory control is in the off position.

Place F and R control in neutral. (*See Neutral Safety Switch*.)

Turn ignition switch and engage starter by pushing starter button.

Do not crank engine for more than 30 seconds continuously to prevent possible damage to starter motor. Release pressure on starter when engine fires.

Warm up engine and check instruments. Engine oil pressure should be a minimum of 25 pounds at 1000 rpm and ammeter should move in charge direction.

For detailed instructions on power unit see *Engine Operating Instructions*, page 12, and *Engine Overhaul*, page 45.

OPERATING GEARS

The gear range transmission has the following three speed ranges:

Compaction Gear (low gear) - provides 0-3.5 mph and should be used when compacting most materials.

Travel Gear (second gear) - provides 0-6.9 mph and should be used for roading the machine from one location to another.

High Gear - should be used in limited applications only.

TO START, STOP, AND REVERSE ROLLER

Check to make sure area is clear all around roller.

With the engine and hydraulic system properly warmed up, set engine speed at 2200 rpm using throttle control and maintain this speed during the entire time this machine is operated, either compacting or traveling.

With the engine running and the forward-reverse and roller speed control in the neutral position, shift the gear range transmission to the desired range. The forward-reverse lever may have to be jockeyed slightly to help snap in the gear range transmission.

Release parking brake.

Before movement in any direction, check again to make sure area is clear all around roller.

Move the forward-reverse and roller speed control from its neutral position toward the desired direction of travel until the desired roller speed is reached. Maintain engine rpm at 2200.

CAUTION

Do not operate the roller continuously above 180° hydraulic oil temperature. Should the roller be in travel or high gear range and the oil temperature reaches 180°, shift to the next lower gear range.

Should damage occur to the hydrostatic drive line, stop roller and shut off engine immediately. The foot operated brakes are provided to ensure a safe stop in this event.

To stop roller, slowly move forward-reverse lever to neutral. The hydrostatic drive will provide all of the braking needed for the normal stopping operation of the roller.

To reverse direction, move forward-reverse lever in the direction of travel desired.

ENGINE SHUTDOWN

Normal engine shutdown is accomplished by pulling out the T-handle marked PULL TO STOP, which cuts off fuel supply, and turning off ignition key, which de-energizes circuit to starter.

Emergency engine button is accomplished by pulling out the T-handle marked EMERGENCY STOP, which cuts off air supply to engine. Do not use this for normal cutoff.

AVERAGE ROLLING CONDITIONS

Operate in compaction gear range.

Maintain engine speed at 2200 rpm.

Do not operate with hydraulic oil temperature above 180°.

Do not overheat engine coolant. Keep water temperature below 200°.

Do not attempt to change gear range without stopping roller.

HAULING

When hauling the roller, the frame should be blocked under both sides at the roll end to prevent overstressing of the roll rubber mount blocks when chaining down and to prevent frame bouncing.

DRIVE CLUTCH

The double pump drive connecting the engine to the hydrostatic pumps is equipped with a clutch, which can be disengaged should the hydrostatic or other drive elements need service. This will allow the operation of the engine and power steering as an aid to towing and loading of the machine. It can also be used as an aid to engine service. The clutch lever can be reached from the inside of the drive compartment.

ENGINE OPERATING INSTRUCTIONS

PREPARATION FOR STARTING ENGINE FIRST TIME

Before starting an engine for the first time, carefully read and follow these instructions. Attempting to run the engine before studying these instructions may result in serious damage to the engine.

NOTE

When preparing to start a new or overhauled engine or an, engine which has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see Daily Operations in the Lubrication and Preventive Maintenance Chart.

Cooling System

Install all of the draincocks or plugs in the cooling system (draincocks are removed for shipping).

Open the cooling system vents, if the engine is so equipped.

Remove the filler cap and fill the cooling system with clean, soft water or a protective solution consisting of high boiling point-type antifreeze, if the engine will be exposed to freezing temperatures. Refer to Engine Coolant. Keep the liquid level about two inches below the filler neck to allow for fluid expansion.

Use a quality rust inhibitor if only water is used in the cooling system.

Close the vents, if used, after filling the cooling system.

Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 25 psi (172 kPa) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine startup. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use heavy-duty lubricating oil as specified under Lubricating Oil Specifications. Then remove the dipstick, wipe it with a clean cloth, insert it, and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the full mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with heavy-duty lubricating oil as specified. Then prelubricate the upper engine parts by removing the valve rocker covers and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms.

Air Cleaner

If the engine is equipped with oil bath air cleaners, fill the air cleaner oil cups to the proper level with clean engine oil. Do not overfill.

Transmission

Fill the transmission case to the proper level with the lubricant specified under Lubrication and Preventive Maintenance.

Fuel System

Fill the fuel tank with the fuel specified under *Diesel Fuel Oil Specifications*.

If the unit is equipped with a fuel valve, it must be opened.

To ensure prompt starting, fill the fuel system between the pump and the fuel return manifold with fuel. If the engine has been out of service for a considerable length of time, prime the filter between the fuel pump and the injectors. The filter may be primed by removing the plug in the top of the filter cover and slowly filling the filter with fuel.

In addition to the above, on an engine equipped with a hydrostarter, use a priming pump to make sure the fuel lines and the injectors are full of fuel before attempting to start the engine.

NOTE

The fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

Lubrication Fittings

Fill all grease cups and lubricate at all fittings with an all-purpose grease. Apply lubricating oil to the throttle linkage and other moving parts and fill the hinged cap oilers with a hand oiler.

Drive Belts

Adjust all drive belts as recommended under *Lubrications and Preventive Maintenance.*

Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of petroleum jelly, and the electrolyte must be at the proper level.

NOTE

When necessary, check the battery with a hydrometer; the reading should be 1.265 or higher. However, hydrometer readings should always be corrected for the temperature of the electrolyte.

Clutch

Disengage the clutch, if the unit is so equipped.

STARTING

Before starting the engine for the first time, perform the operations listed under *Preparation For Starting Engine First Time.*

Before a routine start, see *Daily Operations* in the *Lubrication and Preventive Maintenance Chart*.

If a manual or an automatic shutdown system is incorporated in the unit, the control must be set in the open position before starting the engine.

The blower will be seriously damaged if operated with the air shutoff valve in the closed position.

Starting at air temperatures below 40°F (4°C) requires the use of a cold weather starting aid. *See Cold Weather Starting*.

The instructions for the use of a cold weather fluid starting aid will vary dependent on the type being used.

Reference should be made to these instructions before attempting a cold weather start.

CAUTION

Starting fluid used in capsules is highly inflammable, toxic, and possesses anesthetic properties.

Initial Engine Start (Electric)

Start an engine equipped with an electric starting motor as follows: Set the speed control lever at part throttle, then bring it back to the desired no-load speed. In addition, on mechanical governors, make sure the stop lever on the governor cover is in the RUN position. Then press the starting motor switch firmly. If the engine fails to start within 30 seconds, release the starting switch and allow the starting motor to cool a few minutes before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

CAUTION

To prevent serious damage to the starter, if the engine does not start, do not press the starting switch again while the starting motor is running.

RUNNING

Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, stop the engine and check the lubricating oil system. The minimum oil pressure should be at least 18 psi (124 kPa) at 1200 rpm. The oil pressure at normal operating speed should be 40-60 psi (276-414 kPa).

Warm Up

Run the engine at part throttle and no-load for approximately five minutes, allowing it to warm up before applying a load.

If the unit is operating in a closed room, start the room ventilating fan or open the windows, as weather conditions permit, so ample air is available for the engine.

Clutch

Do not engage the clutch at engine speeds over 1000 rpm.

Inspection

While the engine is running at operating temperature, check for coolant, fuel, or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

Engine Temperature

Normal engine coolant temperature is 160-185°F (71-85°C).

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain back into the crankcase for approximately 20 minutes, and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the heavy-duty lubricating oil specified under *Lubricating Oil Specifications*.

Cooling System

Remove the radiator or heat exchanger tank cap slowly after the engine has reached normal operating temperature and check the engine coolant level. The coolant level should be near the top of the opening. If necessary, add clean, soft water or a high boiling point-type antifreeze. (Refer to *Engine Coolant*).

Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings, and rapid accumulation of sludge in the engine.

CAUTION

When prolonged engine idling is necessary, maintain at least 800 rpm.

STOPPING

Normal Stopping

1. Release the load and decrease the engine speed. Put all shift levers in the neutral position.

2. Allow the engine to run at half speed or slower with no load for a short time, then move the stop lever to STOP to shut down the engine.

Emergency Stopping

If the engine does not stop after using the normal stopping procedure, pull the EMERGENCY STOP knob all the way out. This control cuts off the air to the engine. Do not try to restart again until the cause for the malfunction has been found and corrected.

CAUTION

The emergency shutdown system should never be used except in an emergency. Use of the emergency shutdown can cause oil to be sucked past the oil seals and into the blower housing.

The air shutoff valve, located on the blower air inlet housing, must be reset by hand and the EMERGENCY STOP knob pushed in before the engine is ready to start again.

Fuel System

If the unit is equipped with a fuel valve, close it. Fill the fuel tank; a full tank minimizes condensation.

Exhaust System

Drain the condensation from the exhaust line or silencer.

Cooling System

Drain the cooling system if it is not protected with antifreeze and freezing temperatures are expected. Leave the drains open. Open the raw water drains of a heat exchanger cooling system.

Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 20 minutes) back into the crankcase, and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the heavy-duty lubricating oil specified under Lubricating Oil Specifications.

Transmission

Check and, if necessary, replenish the oil supply in the transmission.

Clean Engine

Clean and check the engine thoroughly to make certain it will be ready for the next run.

Refer to Lubrication and Preventive Maintenance and perform all of the daily maintenance operations. Also perform the operations required for the number of hours or miles the engine has been in operation.

Make the necessary adjustments and minor repairs to correct difficulties which became apparent to the operator during the last run.

OPERATING CONTROLS

Operator controls (Fig. 1) have been provided for maximum flexibility of roller operation. The operator is placed in such a position that he may see the front or rear of the machine without sacrificing hand control of direction and speed.

Instrument Panel (1)

The engine instruments and controls are mounted on the right-hand side of the steering column.

Steering

Roller steering is the automotive hydraulic power-type with center-hinge body pivot (articulated).

Engine Throttle (2)
To be set and maintained at 2200 rpm after warm up period.

Engine Tachometer (3)
Indicates engine speed setting.

Parking Brake (4)
The parking brake is operated by a lever attached to the platform on the left side of the operator. Brake band adjustment is obtained by rotating knurled knob on the top of the lever.

Forward-Reverse and Roller Speed Control (5)
The forward-reverse and roller speed control are combined into one lever located on top of the console located to the left of the operators position. Movement of this lever from neutral position causes the hydrostatic transmission to drive the roller either forward or reverse, depending on the direction in which the lever is moved.

Continued movement of the control lever increases travel speed in the direction selected.

CAUTION

During engine and hydraulic system warmup, leave control lever in neutral position.

Gear Range Lever (6)
The gear range lever located on the side of the console provides three ranges with a neutral position between each range. Detents provide a positive location for each range and neutral. The compaction gear position is slightly above the horizontal and the highgear position is vertical, with the travel gear position equally spaced between the compaction and high-gear range.

Brake Pedal (7)
Hydraulic wheel brakes are provided for use in the event of an emergency only.

To stop roller, slowly move forward- reverse lever to neutral. The hydrostatic drive will provide all the braking needed for the normal operation of the roller.

Vibrator Frequency Control Lever (8)
The vibratory control lever is fastened to the left side of the steering console. Moving the lever down increases vibrator frequency for moving to the left. With respect to the position of the operator, the lever should move up for travel to the right.

Centering the levers (detent position) stops the vibrators. Screwing the lever handle in or out will adjust the vibratory frequency. (Out increases frequency.) These controls must be shut off before stopping roller or when roading.

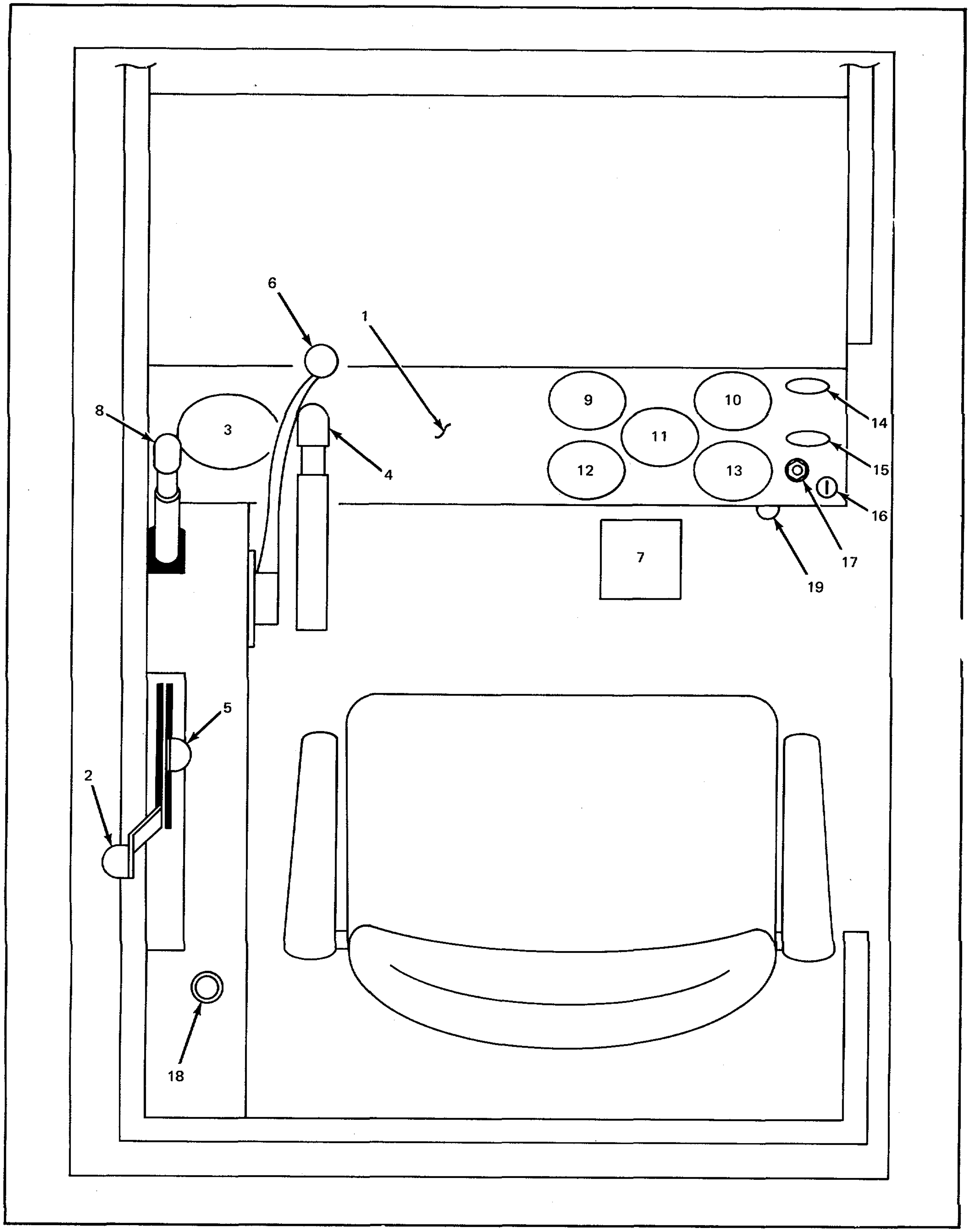


Figure 1. Operating Control Locations

Water Temperature Gage (9)

Engine Oil Pressure Gage (10)

AMP Meter Gage (11)

Fuel Gage (12)

Hydraulic Oil Pressure Gage (13)

Emergency Stop Lever (14)

Fuel Stop Lever (Normal Stopping Device) (15)

Ignition Switch (16)

Starter Button (17)

Horn Button (18)

Light Switch (19)

ROLLING INSTRUCTIONS

Vibrator Frequency Adjustment

Frequency of the vibrator is controlled by the operation of the vibrator control lever which regulates the oil flow to the hydraulic motor on the vibrator drive. The highest frequency does not necessarily produce the greatest compaction force. Most efficient compaction occurs when the material being compacted is vibrated at its own natural frequency; that is, the frequency at which it wants to vibrate. Magnification of the vibrating force by 5 to 50 times can be obtained by vibrating at the natural frequency of the earthroller mass combination.

Resonant frequency of most highway construction materials will fall in the range of 1100 to 1500 vibrations per minute for this roller. The amplitude of vibration (movement) of the roll will be greatest when it is operating at the natural frequency of the material being compacted.

Rolling Speed

The recommended rolling speed is from 1 to 3 mph.

Number of Passes

The number of passes vary, of course, with the amount of lift and the material being compacted. Specified density may normally be reached after two or three passes. Caution should be used not to make too many passes and over vibrate the material, because this may tend to pulverize the material, or cause it to loosen near the surface.

Rolling Heavy Loose Lift

When rolling a heavy loose lift, the first pass should be made with the roll first to improve the footing for the drive wheels.

Construction Engineering Data

For guidance in the optimum use of this equipment under varying soil conditions, operators should refer to TM 5331A, Utilization of Engineer Construction Equipment; Volume A, Earthmoving, Compaction, Grading, and Ditching Equipment.

CHAPTER III

MAIMTENANCE

PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)

(See page 427 for Engine PMCS)

Maintenance Forms and Records

Every mission begins and ends with paperwork. There isn't much of it, but you have to keep it up. The forms and records you fill out have several uses. They are a permanent record of the services, repairs, and modifications made on your vehicle. They are reports to organizational maintenance and to your commander. And they are a checklist for you when you want to know what is wrong with the vehicle after its last use, and whether those faults have been fixed. For the information you need on forms and records, refer to TM 38-750.

Preventive Maintenance Checks and Services:

1. Do your before (B) PREVENTIVE MAINTENANCE just before you operate the vehicle. Pay attention to the CAUTIONS and WARNINGS.

2. During (D) checks and services of PREVENTIVE MAINTENANCE will be performed while the equipment and/or its component systems are in operation.

3. Do your after (A) PREVENTIVE MAINTENANCE right after operating the vehicle. Pay attention to the CAUTIONS and WARNINGS.

4. Do your weekly (W) PREVENTIVE MAINTENANCE weekly.

5. Do your monthly (M) PREVENTIVE MAINTENANCE once a month.

6. If something doesn't work, troubleshoot it with the instructions in this manual or notify your supervisor.

7. Always do your PREVENTIVE MAINTENANCE in the same order so it gets to be a habit. Once you've had some practice, you'll spot anything wrong in a hurry.

8. If anything looks wrong and you can't fix it, write it on your DA Form 2404. If you find something seriously wrong, report it to organizational maintenance RIGHT NOW.

9. When you do your PREVENTIVE MAINTENANCE, take along the tools you need to make all the checks. You always need a rag or two.

   a. Keep it clean: Dirt, grease, oil, and debris only get in the way and may cover up a serious problem. Clean as you work and as needed. Use dry-cleaning solvent SD-2 on all metal surfaces. Use soap and water when you clean rubber or plastic material.

   WARNING

   Dry-cleaning solvent, used to clean parts, is potentially dangerous to personnel and property. Do not use near open flame or excessive heat. Flash point of solvent is 100°F - 1380F.

   b. Bolts, nuts, and screws: Check them all for obvious looseness, and missing, bent, or broken condition. You can't try them all with a tool, of course, but look for chipped paint, bare metal, or rust around boltheads. If you find one you think is loose, tighten it, or report it to organizational maintenance if you can't tighten it.

c. Welds: Look for loose or chipped paint, rust, or gaps where parts are welded together. If you find a bad weld, report it to organizational maintenance.

d. Electric wires and connectors: Look for cracked or broken insulation, bare wires, and loose or broken connectors. Tighten loose connectors and make sure the wires are in good shape.

e. Hoses and fluid lines: Look for wear, damage, and leaks, and make sure clamps and fittings are tight. Wet spots show leaks, of course. But a stain around a fitting or connector can mean a leak. If a leak comes from a loose fitting or connector, tighten it. If something is broken or worn out, report it to organizational maintenance.

10. It is necessary for you to know how fluid leakage affects the status of your vehicle. The following are definitions of the types/classes of leakage an operator or crew member needs to know to be able to determine the status of his/her vehicle. Learn and then be familiar with them, and REMEMBER - WHEN IN DOUBT, NOTIFY YOUR SUPERVISOR!

Leakage Definitions for Crew/Operator PMCS

Class I	Seepage of fluid (as indicated by wetness or discoloration) not great enough to form drops.
Class II	Leakage of fluid great enough to form drops but not enough to cause drops to drip from item being checked/inspected.
Class III	Leakage of fluid great enough to form drops that fall from the item being checked/inspected.

CAUTION

Equipment operation is allowable with minor leakages (Class I or II). Of course, consideration must be given to the fluid capacity in the item/system being checked/inspected. When in doubt, notify your supervisor.

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B - Before D - During A - After W - Weekly M - Monthly

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NECESSARY	EQUIPMNET IS NOT READY/ AVAILABLE IF:
						NOTE Perform weekly as well as before PMCS if: You are the assigned operator but have not operated equipment since the last weekly. -or- You are operating the equipment for the first time.	
1						GENERAL	
	●					a. Visually check for loose wiring, damaged piping, or hoses.	
	●	●				b. Look for evidence of fluid leakage (oil, fuel, coolant).	Class III leaks or any fuel leakages are found.
2	●					ENGINE CRANKCASE Check dipstick for proper level. Add oil as necessary to FULL mark.	
3	●					RADIATOR Check coolant level. Add coolant as required. (Level should be approximately one inch from bottom of filler neck.)	
4	●					FUEL STRAINER Drain approximately 1/4 pint to remove sediment and water.	
5						TIRES	
	●					a. Check for cuts and general condition.	One or more missing, flat, and/or unserviceable.

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B - Before D - During A - After W - Weekly M - Monthly

ITEM NO	INTERVAL B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NECESSARY	EQUIPMNET IS NOT READY/ AVAILABLE IF:
5						TIRES (CONT)	
	●					b. Check for correct air pressure (16 psi).	
6	●					ROLL SCRAPER	
						Check clearance between scraper and roll. (Clearance should be approximately 7/8 inch.)	Clearance incorrect.
7	●					VIBRATING ROLL BUMPERS	
						Check clearance between rubber bumper and suspension beam. (Clearance should be approximately 1/8 inch.)	Clearance incorrect.
8	●					HYDROSTATIC DRIVE RESERVOIR	
						Check fluid level sight gage on reservoir. Add as required.	
9	●					ROLL AXLE BEARINGS	
						Lubricate until grease appears from under seal in inner end of bushing next to roll head.	
10						CONTROLS AND INSTRUMENTS (Check for proper indication and operation.)	Engine coolant, oil pressure, or hydraulic oil temperature gages indicate abnormal operation.
		●				a. Engine coolant temperature gage 160°-180°F normal operation	
		●				b. Engine Oil Pressure Gage 40-60 psi normal operation	
		●				c. Ammeter Slight (+) charge	
		●				d. Hydraulic Oil Temperature Gage 100°-180°F normal operation	

OPERATOR/CREW PREVENTIVE MAINTENANCE CHECKS AND SERVICES

B - Before D - During A - After W - Weekly M - Monthly

ITEM NO	B	D	A	W	M	ITEM TO BE INSPECTED PROCEDURE CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NECESSARY	EQUIPMNET IS NOT READY/ AVAILABLE IF:
10						CONTROLS AND INSTRUMENTS (Check for proper indication and operation.) (CONT)	
		●				e. Tachometer 2200 rpm normal operation	
		●				f. Fuel Gage	
		●				g. Controls (i.e., steering, shift-ing, etc.) Check for proper operation.	
11						AIR CLEANER	
		●				a. Check air cleaner indicator; red, clean and service element.	Element missing.
				●		b. Inspect air cleaner element.	
12				●		BRAKE MASTER CYLINDER Check fluid level. Add as required to 1/2 inch below top of reservoir.	
13				●		POWER STEERING RESERVOIR (hot check) Check fluid level. Add as required to 4 inches below breather.	
14					●	V-BELTS Check for frayed, cracked, or broken belts.	
15					●	BATTERY Check fluid level. Fill as required to split ring. Inspect for obvious defects, such as cracked case, or burnt, broken, or loose terminal and cables.	Missing or will not crank engine.

ORGANIZATIONAL PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Q - Quarterly S - Semiannually A - Annually B - Biennially H - Hours M - Miles

ITEM NO	INTERVAL Q	S	A	B	H	MI	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NEEDED
1	●						ENGINE
							Check for leaks, loose mounts, and proper operation.
2					100		OIL FILTER (Engine)
							Change oil and filter element.
3					300		FUEL FILTER AND STRAINER
							Change filter element and strainer element.
4					200		V-BELTS
							Check tension.
5							AIR CLEANER
	●						a. Check filter element and clean as required.
					500		b. Change filter element.
6		●					BLOWER SCREEN
							Check and clean if required.
7					100		BATTERY
							Check specific gravity of electrolyte in each cell.
8							RADIATOR
	●						a. Check for leaks and clean exterior as required.
		●					b. Check antifreeze protection.
					1000		c. Drain and flush radiator and engine.
9		●					GAGES AND CONTROLS
							Check operation.

ORGANIZATIONAL PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Q - Quarterly S - Semiannually A - Annually B - Biennially H - Hours M - Miles

ITEM NO	Q	S	A	B	H	MI	ITEM TO BE INSPECTED PROCEDURE: CHECK FOR AND HAVE REPAIRED, FILLED, OR ADJUSTED AS NEEDED
10	●						TIRES Check for cuts and general condition. Check tire pressure (16 psi).
11				200			HYDROSTATIC DRIVE FILTER Replace filter element. **NOTE** Install new element if service is required on any component.
12			●				HYDROSTATIC DRIVE RESERVOIR Drain and refill.
13			●				GEAR RANGE TRANSMISSION Drain and refill.
14			●				PUMP GEAR DRIVEN Drain and refill.
15			●				ECCENTRIC SHAFT BEARINGS Drain and refill.
16	●						DRIVE AXLE (planetary and differential) Check level and add as required.

LUBRICATION CHART

ITEM NO	LUBRICATION POINTS	LUBRICANT	INSTRUCTIONS
		DAILY	
8	Hydrostatic Drive Reservoir	Automatic Transmission Fluid, Type F	Check fluid level sight gage.
1	Engine		Refer to Engine Maintenance Section.
		FIRST WEEK	
18	Hydrostatic Drive Filter	10 Micron Filter	Replace.
		WEEKLY	
2	Engine Air Cleaner	See Engine Maintenance Section.	
3	Power Steering Reservoir	Auto Transmission Fluid Type A	Check and fill to 4 inches below breather when hot.
4	Steering Joint Bearings	GAA Grease	One fitting top and one bottom of yoke.
5	Oscillating Thrust Washer	GAA Grease	One fitting each side of crossbeam in yoke.
6	Steering Cylinder Bearings	GAA Grease	One fitting each end of cylinders.
7	Clutch Throw Out Bearings	GAA Grease	
9	Clutch Lever Shaft	GAA Grease	
10	U-Joint Drive Shaft	GAA Grease	One fitting each cross and one fitting slip joint.

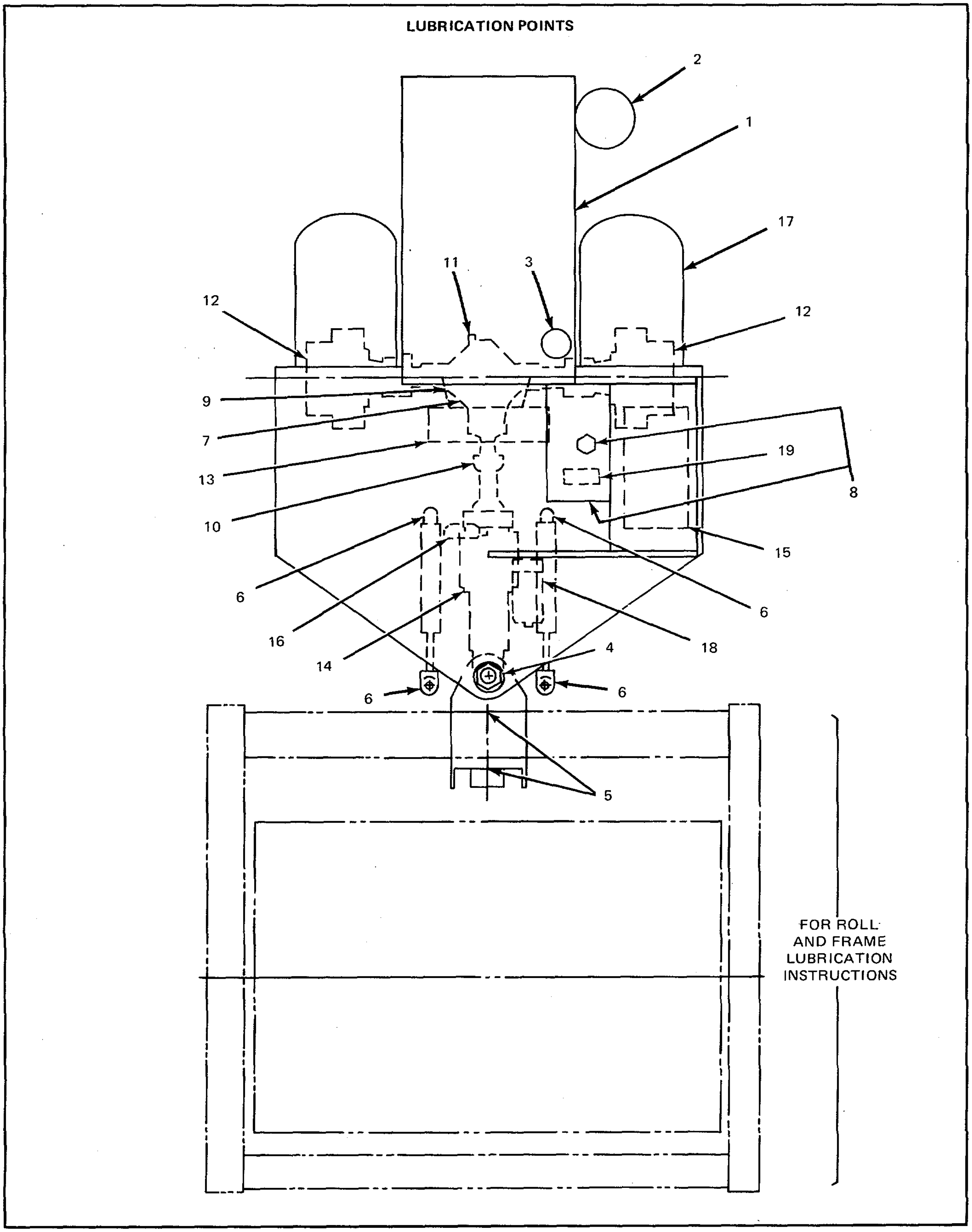


Figure 1. Lubricating Points

LUBRICATION CHART

ITEM NO	LUBRICATION POINTS	LUBRICANT	INSTRUCTIONS
11	Drive Axle Differential	G085W/140 Hypoid Gear Lube	Fill to level plug.
12	Drive Axle Planetary	G085W 140 Hypoid Gear Lube	Fill to level plug.
13	Pump Gear Drive	G080W/90	Fill to level plug (located approximately 2 inches below center-line of unit).
14	Gear Range Transmission	G080W/90	Fill to level plug.
15	Battery		Maintain level.
16	Brake Master Cylinder	VV-B-680	Fill to 1/2 inch below top of reservoir.
17	Recommended Tire Air Pressure:		
		23.1-26 All-Weather Tire 16 psi	
	EVERY 60 DAYS OR 200 WORKING HOURS		
18	Hydrostatic Drive Filter	10 Micron Filter Element	Replace. (NOTE: Install new element if field service required on any component.)
8	Hydrostatic Drive Oil Reservoir		Check tank breather.
	EVERY 6 MONTHS OR 1000 WORKING HOURS		
13	Pump Gear Drive	G080W/90	Drain and refill.
14	Gear Range Transmission	G080W/90	Drain and refill. Refer to Funk Transmission Service Manual.

Figure 2. Lubrication Plate

LUBRICATION CHART

ITEM NO	LUBRICATION POINTS	LUBRICANT	INSTRUCTIONS
	EVERY YEAR OR 2000 WORKING HOURS		
8	Hydrostatic Drive Oil Reservoir	Automatic Transmission Fluid Type F	Drain and refill.
19	Screen (located in oil reservoir) should only be removed and cleaned should clogging prevent system from working properly. Refer to Sundstrand troubleshooting procedure.		

NOTE:

Stop engine before checking or adding oil.

Clean around oil fill before checking or adding oil.

The oil in the unit should be changed whenever the oil shows traces of dirt or effects of high temperature, evident by discoloration or strong odor.

Drain dirty oil while the unit is warm.

Clean all magnetic drainplugs before replacing.

Do not overfill.

LUBRICATION CHART

ITEM NO	LUBRICATION POINTS	LUBRICANT	INSTRUCTIONS
	EVERY DAY OR 8 WORKING HOURS		
1	Roll Stub Axle Bearings	GAA Grease	One fitting each of the roll thrust cap. Lubricate until grease appears from under seal in inner end of bushing next to roll head.
	EVERY WEEK OR 50 WORKING HOURS		
2	Jackshaft Pillow Block and Flange Bearing	GAA Grease	One fitting each.
3	Eccentric Shaft Bearings	G080W/90	Check oil level plug on both sides. Plug located on bearing housing flange near roll head .*
	*Check each morning before operating roller. The roller must be on level ground when checking oil level and roll should be in a position so that the fill-drain plug (1-inch pipe plug) is in the top most position. This will put the oil level plug (3/8-inch pipe plug) in its proper location as shown in fig. 4.		
4	Drive Sheave Bearings	GAA Grease	1-90° fitting on inside frame above eccentric drive shaft.
5	Eccentric U-Joint Slip Spline	GAA Grease	One fitting on slip joint.
	EVERY 6 MONTHS OR 1000 WORKING HOURS		
3	Eccentric Shaft Bearings	G080W/90	Drain and refill (see special instructions for 50-hour check).
6	Eccentric U-Joint and Outer Cross	GAA Grease	Two fittings - one each cross.

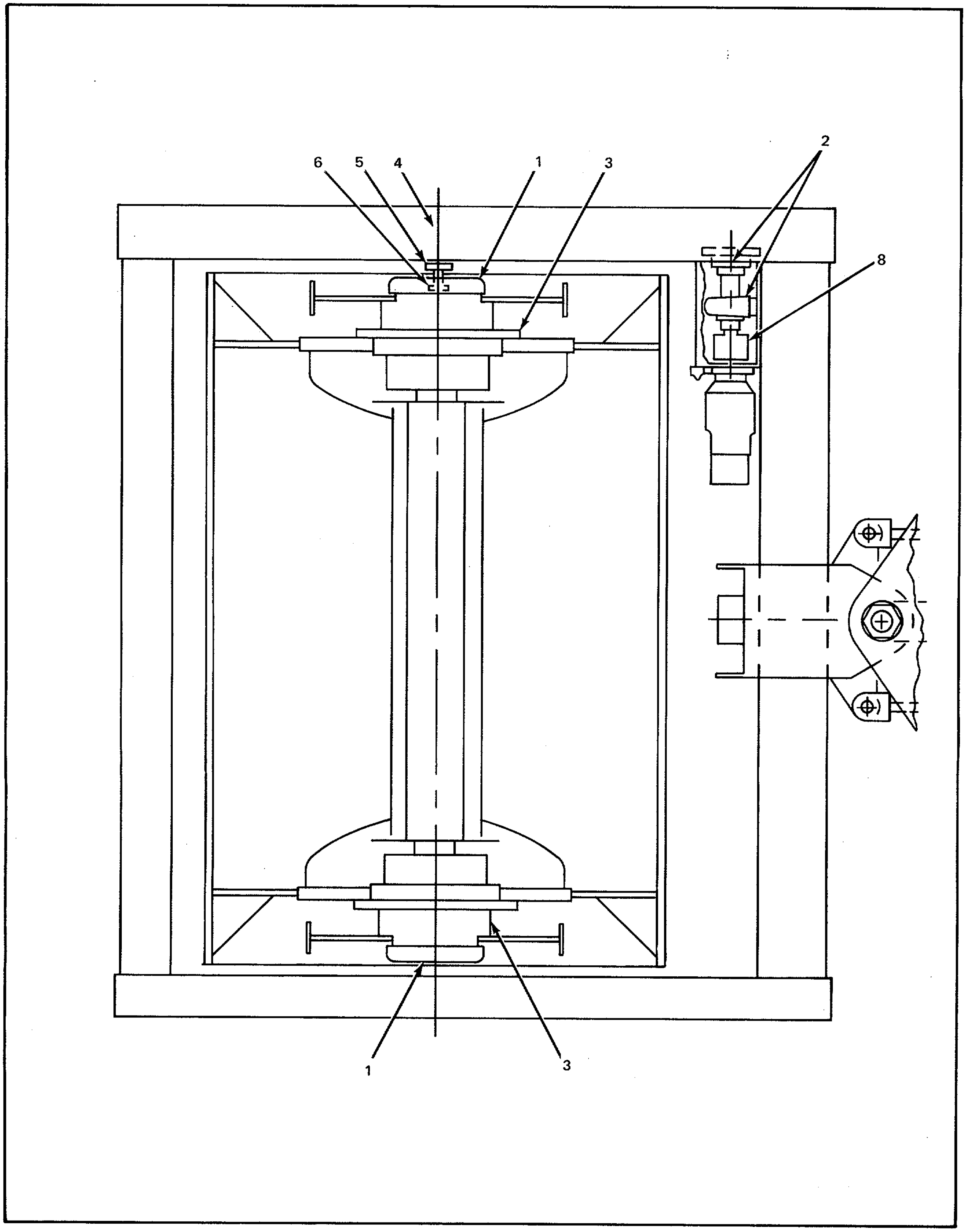


Figure 3 . Roller Lubricating Points

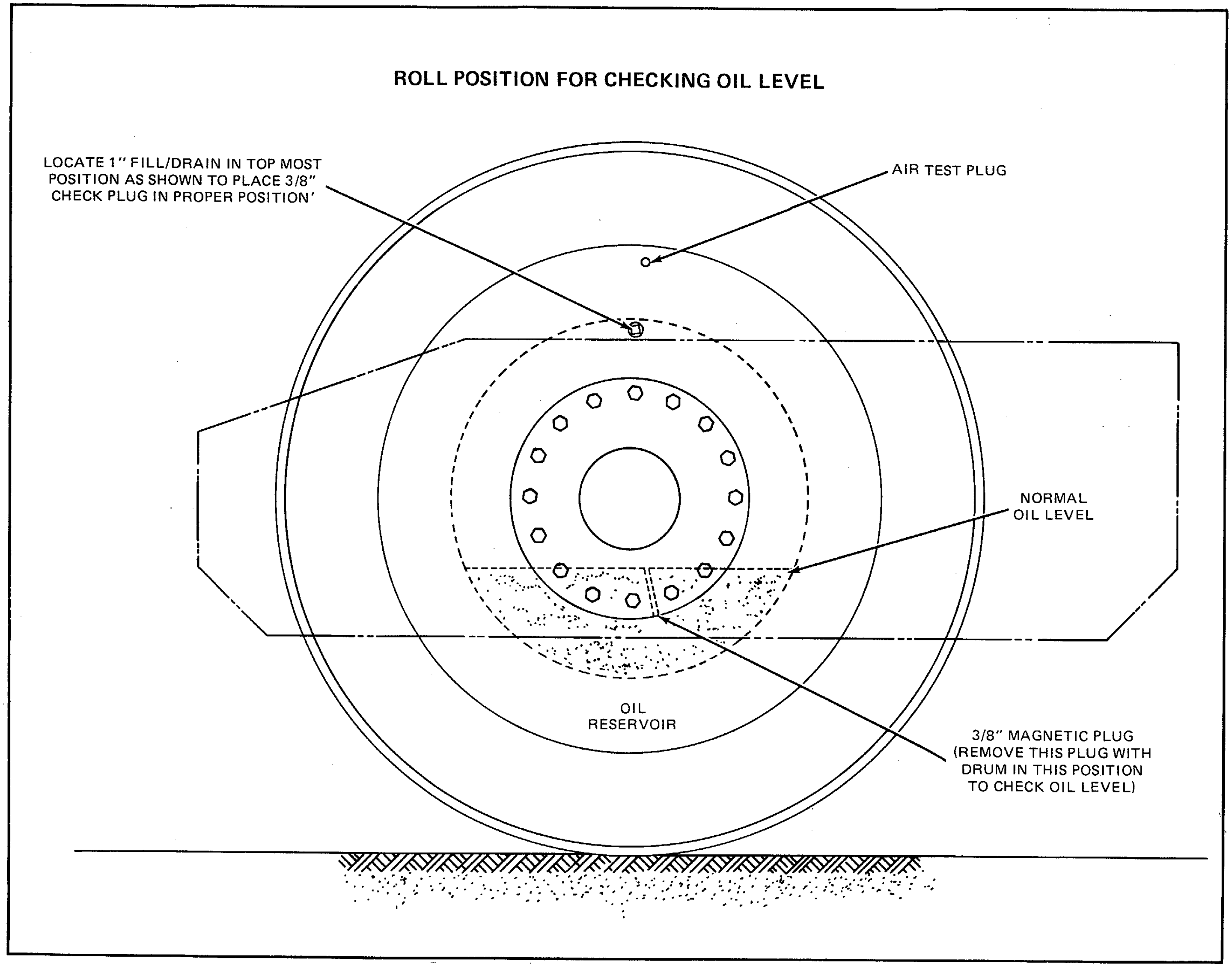


Figure 4. Roll Position For Checking Oil Level.

LUBRICATION CHART

ITEM NO	LUBRICATION POINTS	LUBRICANT	INSTRUCTIONS
	EVERY YEAR OR 2000 WORKING HOURS		
8	Coupling Vibratory Drive	GAA Grease	Repack.

ROLLER MAINTENANCE

Engine

For detailed operating and maintenance instructions, see Engine Operating Instructions, page 12, and Engine Overhaul, page 45.

Daily Checks:

Coolant level	Air intake connections and air cleaner
Crankcase oil level	Coolant hoses
Exhaust system	Fan belts and miscellaneous
Fittings on injection lines	

Power Steering

Power steering system consists of pump and reservoir, orbitrol and booster cylinders, and connecting hoses.

Daily inspection shall be made to be certain that all hydraulic connections are tight. A loose connection will allow fluid to escape and cause air to be drawn into the system, resulting in noisy and erratic operation.

Inspect hydraulic fluid in the reservoir for evidence of foreign particles. When contamination is found, the system shall be drained. Clean reservoir thoroughly before refilling. Remove all lint particles to avoid possible clogging of system filter. Refill reservoir with new automatic transmission fluid, type A, poured through a filtered or screened funnel.

When filling, permit oil to settle into the system and fill the reservoir. Start engine, and, while maintaining oil level in the reservoir, turn the steering wheel slowly to the right and left to purge air from the system. Oil level should be at FULL position when hot. For troubleshooting and additional inspection and maintenance information, see Power Steering information on page 555.

Brakes

Check brakes occasionally for proper adjustment.

Shoes are adjusted in a conventional manner by a star wheel ratchet accessible through the backup plate assembly.

Check fluid in master cylinders for proper level and keep plumbing fittings tight to prevent leaks in system.

Inspect hydraulic brake lines frequently for abrasive wear against frame members or rotating wheel parts, and accidental kinks and sharp bends.

Parking Brake

Minor adjustment and takeup of parking brake is accomplished by rotating knurled knob on parking brake handle.

Differential Axle

See Lubrication Chart.

Articulated Hinged Joints

These joints are equipped with heavy- duty, self-aligning bearings which can be adjusted to take up any looseness which may occur. Adjustment is made by turning the hex nuts, one located on top and one on bottom of hinged joint. Adjust top and bottom nuts alternately, a little at a time, checking after each adjustment to maintain an equal gap above and below the yoke assembly. Caution should be taken not to overtighten.

ROLLER MAINTENANCE

Air Cleaner Service Procedure

The air cleaner should be inspected periodically to maintain maximum engine protection and maximum service life. These inspections should include the following points:

Inspect the air transfer duct between the air cleaner and the engine to be sure all clamps are tight and there are no cracks in the ducting.

Air cleaner mounting bolts and clamps must be tight to hold the air cleaner securely.

Check for dents and damage to the air cleaner which could mean a leak.

Make sure all inlet accessories are free from obstruction and securely mounted.

Check precleaner fins for plugging.

Clean element with compressed air (maximum 100 psi) or by washing in water and detergent solution. Inspect for ruptures, holes, or damaged gaskets. Replace after six cleanings or annually, whichever occurs first.

Hydrostatic Drive Oil Filter

When tightening, center post hold housing from turning, otherwise the O-ring may stretch out of shape causing leak- age. Tighten center post to a maximum of 20 ft-lb.

V-Belt Adjustment - Vibratory Drive

The vibrator shaft V-belt drive consists of a four V-belt band. Adjustment of the belt tension is made with the tension bolt located in the rear right side of the frame.

To adjust belts, loosen the jamnut on the tension bolt. Wrenching the nut in tightens the belt. The belt tension may be checked through a round hole in the side of the frame, which is located at the upper side of the belt drum near the center between the sheaves.

Check the tension adjustment frequently on new belts until the initial stretch is out.

Vibrating Roll Bumpers

The bumpers are provided to limit the movement of roll to the front and rear. However, the roll must be free to vibrate, therefore, the brackets should be adjusted to maintain approximately 1/8-inch clearance between the rubber bumpers and the suspension beam.

Roll Scrapers

The scrapers are the fixed type and should be adjusted to clear the roll approximately 7/8-inch when not operating. This will allow sufficient clearance for the roll to vibrate without striking the scrapers and still keep the roll clean.

Vibrating Shaft Assembly

Under normal operating conditions, no maintenance is required except as specified in the lubrication instructions. The eccentric shaft has two spherical roller bearings, one on each end. The normal operating temperature should not exceed 180°F. If operating temperature ranges between 1800 and 200°F due to abnormal ambient temperatures, replace the oil with the next higher grade. To measure the oil temperature, park the roller with the filler-drain plug near the top of the roll and remove the filler-drain plug. Insert the sensing unit of a Stewart Warner D-361 or equivalent gauge through the filler-drain hole, and feed most of the tube into the drum to be sure the sensing unit is submerged in oil. Leave the sensing unit in the oil until the temperature gauge reading stabilizes. Remove the sensing unit and replace the plug.

ROLLER MAINTENANCE

Eccentric Shaft Oil Seal Replacement

When it becomes necessary to change the eccentric shaft oil seal, it may be done without removing the roll from the frame or the eccentric shaft from the roll.

To remove the eccentric shaft oil seal, remove sheave access covers and belts from the frame. The eccentric shaft sheave with shaft, bearings, and housing, and half of the drive shaft may be removed by unscrewing the drive shaft dust cover and unbolting the sheave mounting assembly from the frame.

Next, unbolt the inner half of the drive shaft from the eccentric shaft and remove the remaining four bolts from the end of the eccentric shaft; a stub shaft with a collar. Insert a squarehead jackscrew in end of eccentric stub shaft which will remove the stub shaft and collar, and will pull the seal out at the same time.

Seal surface on the eccentric stub shaft is a wear sleeve pressed on the shaft. It should be replaced if grooved or rough. Replacement requires the use of a piece of round material of sufficient length and proper diameter to drive the new seal into place.

Stub shaft, drive shaft, and the remaining assemblies should be replaced in the reverse manner to the disassembly as described above. When reassembling the splined parts of the eccentric drive shaft, make sure the same crosses on both ends of the drive shaft line up (are in the same plane), otherwise uneven speeds will result between the input and output shaft halves.

Eccentric Shaft Bearings

No maintenance is required except as called for in the lubrication instructions. The eccentric shaft has two spherical roller bearings: one in the right-hand end and one in the left-hand end of the roll. Normal operating temperature should not exceed 200°F. To measure the temperature, use a Stewart Warner D-361-T gauge or similar. Rotate the roll until the oil fill drain holes are in top position and remove the plugs, one in each end of the roll near the cone. Insert the temperature gauge sensing unit and feed it until it is submerged in the oil. Wait until temperature gauge reading does not rise anymore to get a true reading. Remove gauge and sensing unit, and replace plugs.

If it becomes necessary to replace an eccentric shaft bearing, the roll and frame must be disconnected. Since the roll weighs 7,200 pounds it will be easier to lift the frame from the roll. (The frame weighs approximately 3550 pounds.) After disconnecting the yoke assembly and the eccentric drive shaft from the power end of the unit, hoist frame up and over the roll. The front and rear scraper bars must also be removed from the machine before lifting frame from roll.

Removal and Replacement of the-L.H. Eccentric Shaft Bearing (Opposite To Drive Side)

Removal - Remove the thrust cap and frame suspension assembly consisting of a suspension beam, rubber mounts, mounting plates, and bearing housing with bronze flange bearings. For the removal of the eccentric shaft bearing from the eccentric shaft and roll, it is necessary to have at least one tool

ROLLER MAINTENANCE

to assist in this operation. The tool consists of a 60 inch length of 3-inch standard black iron pipe with a 1-inch thick plate x 3 1/16 finished O.D. The plate has a 1 1/4-6NC 3 1/4 long grade 5 hex head bolt which is installed in a drilled hole in the center of the plate and with the head of the bolt welded to the plate. The plate and bolt assembly are welded in one end of the pipe. The plate and the bolt must be square with the pipe so that the pipe tool may be screwed in squarely against the end of the eccentric shaft. A print of the above described pipe tool, VRG-610, is available in appendix D.

After screwing the pipe tool in firmly against the end of the eccentric shaft, support the weight of the eccentric shaft and bearing housing to avoid misalignment damage to the eccentric shaft and eccentric bearing housings. To do this, take a strain on the pipe tool with a hoist at approximately halfway out the length of the pipe. Unbolt the eccentric bearing housing from the roll head and remove from the roll head and eccentric shaft by supporting the bearing housing with another hoist and a sling.

After completely removing the eccentric bearing housing with bearing from the roll, the bearing can now be removed from the bearing housing in the following manner: Remove the bearing retainer and the four hex socket setscrew plugs from the bearing housing. Replace the setscrews with four 3/4NC x 8 long heat treated squarehead setscrews, and jack the bearing out of the housing evenly.

Replacement - To reassemble the eccentric bearing in the housing, place the housing in the press with the bearing bore up and place the new bearing squarely in the starting bore of the housing. Next, place the bearing retainer, centered on the bearing in the assembled position, with a thick plate on top of the bearing retainer to provide a pressing surface. Center this assembly under the press ram as nearly as possible and begin slowly pressing the bearing into the housing. Carefully observe and measure the width of the bearing outer race pressed in the housing all around at intervals. If the bearing begins to cock in the housing, shift the assembly so that the ram is pressing off center toward the high side, until the bearing is straightened in the housing. Continue this process until the bearing is far enough in the housing to prevent further cocking, then press the bearing to the bottom of the bore. Replace the bearing retainer plate.

Reassemble the eccentric bearing and housing on the eccentric shaft and in the roll in the reverse procedure as described in the *Removal* instructions.

The bearing inner race is self-aligning and the bore must be aligned perfectly with the eccentric shaft in order to be easily slipped onto the shaft. Because of this bearing feature, it is very helpful to have an aligning tool which works similar to the above described pipe and bolt tool, VRG-610. However, the main difference is that this tool must have a segmented removal slip collar which fits inside the bearing housing hollow stub shaft. By screwing this tool to the end of the eccentric shaft with the bearing and housing assembled on the tool, the bearing bore as well as the bearing housing are positioned concentrically and squarely with the eccentric shaft. By supporting the outer end of the tool with a hoist and aligning the bearing housing with the mating hole in the end of the drum, the bearing housing with bearing may be slipped onto the eccentric shaft off of the tool and into the drumhead. A print for this tool, VRF-325, may be obtained from Tampo on special request.

Removal and Replacement of R.H. Eccentric Shaft Bearing

Removal - To remove the R.H. eccentric shaft bearing, remove the hubcap and frame suspension assemblies from both bearing journals. Remove the L.H. eccentric bearing and housing as previously described under *Removal and Replacement of L.H. Eccentric Shaft Bearing.* Remove the L.H. oil slinger plate from the eccentric shaft. Unbolt the R.H. bearing housing from the roll and install the eccentric shaft and bearing housing aligning tool to prevent possible damage to the shaft seal. This tool consists basically of two tools: a flanged stub shaft which bolts to the end of the eccentric shaft and a counterbored aligning plate which slips over the end of the outside diameter of the bearing housing journal. The aligning plate also has a capped length of tubing long enough to press the eccentric bearing housing onto the eccentric bearing in the reassembly process. Prints of these two tools, VRF-1039A and VRF-1039B, may be obtained from Tampo on special request.

Next, screw the pipe tool VRG-610 into the L.H. end of the eccentric shaft until the pipe is firmly seated against the end of the shaft. Unbolt the R.H. eccentric bearing housing from the roll and, with two hoists and slings, slide the housing and eccentric shaft only far enough out of the roll head to replace the sling with a chain and bolts through two holes in the top of the eccentric bearing housing flange to prevent excessive load on the stub trunnion shaft. Remove the R.H. bearing housing and eccentric shaft from the roll.

The R.H. eccentric bearing is held on the shaft by means of a bearing locknut, so the housing must actually be pressed off of the bearing outer race before the bearing can be removed from the shaft.

Remove the bolts from the bearing retainer plate and the four setscrew plugs from the face of the bearing housing. Replace the setscrews with four 3/4 NC x 8 heat-treated, square- head setscrews and jack the bearing out of the housing. The bearing may now be simply removed from the shaft after re- moving the locknut and lockwasher.

Replacement - To replace the R.H. eccentric shaft bearing, first install the oil slinger plate onto the shaft if removed. Then place the bearing retainer ring and bearing backup ring on the shaft before installing the bearing. The bearing should be tightened against the backup ring with the bearing locknut as tight as reasonably possible and then locked with the bearing lockwasher.

The eccentric shaft assembly (as described above) must now be placed vertically in a press. In order not to put any thrust load on the oil slinger plate (item 3), the assembly must be supported with two bars (approximately 2 inches square x 22 inches long), placed between the oil slinger plate and the bearing retainer plate (when raised and aligned against the bearing outer race). In order to support the assembly with the oil slinger plate above the press crossmembers, two more bars of the required size must be placed crossways under each end of the first two bars.

Before pressing the VRF-138 eccentric bearing housing on the eccentric bearing, the stub shaft part of the aligning tool, (VRF-1039A) must be bolted to the end of the eccentric shaft. The eccentric bearing housing may now be placed over the stub shaft part of the aligning tool and down onto the eccentric bearing. Next, place the VRF-1039B part of the aligning and pressing tool down over the stub shaft part of the aligning tool and the end of the eccentric bearing housing stub journal

ROLLER MAINTENANCE

shaft. These tools will now hold the eccentric bearing and housing square with the eccentric shaft so that the bearing and housing may be pressed onto the eccentric bearing without cocking and binding. Press the housing all the way down onto the bearing until the bearing bottoms in the housing. Next, install the bearing retainer with drilled head bolts and lock wire two bolts together at a time with each lock wire. A print of the above described tools (VRF-1039A and VRF-1039B) may be obtained from Tampo on special request.

Articulated Hinged Joint

The joint is equipped with heavy-duty, self-aligning bearings which can be adjusted to take up any looseness which may occur. Adjustment is made by turning the hex nuts (one located on top and one on bottom of hinged joint). Adjust top and bottom nuts alternately, a little at a time, checking after each adjustment to maintain an equal gap above and below the yoke assembly. Caution should be taken not to overtighten.

Engine Governor Setting

The engine governor has been set at 2355 rpm (no load) and 2200 rpm (full load) (Detroit Diesel 4-53 using 60 x 84 inch roll and frame with standard eccentric shaft).

CLEARANCES AND TORQUE SPECIFICATIONS

Clearances of new parts and wear limits on used parts are listed in tabular form at the end of each section throughout the manual. It should be specifically noted that the *New Parts* clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled *Limits* lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still assure satisfactory performance. It should be emphasized that the figures given as *Limits* must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the paragraph entitled Inspection under *General Procedures* in this section.

Bolt, nut, and stud torque specifications are also listed in tabular form at the end of each section.

PRINCIPLES OF OPERATION

The diesel engine is an internal combustion power unit, in which the heat of fuel is converted into work in the cylinder of the engine.

In the diesel engine, air alone is compressed in the cylinder; then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression.

The Two-Cycle Principle

In the two-cycle engine, intake and exhaust take place during part of the compression and power strokes respectively as shown in Fig. 1. In contrast, a four-cycle engine requires four piston strokes to complete an operating cycle; thus, during one half of its operation, the four-cycle engine functions merely as an air pump. A blower is provided to force air into the cylinders for expelling the exhaust gases and to supply the cylinders with fresh air for combustion. The cylinder wall contains a row of ports which are above the piston when it is at the bottom of its stroke. These ports admit the air from the blower into the cylinder as soon as the rim of the piston uncovers the ports as shown in Fig. 1 (scavenging).

The unidirectional flow of air toward the exhaust valves produces a scavenging effect, leaving the cylinders full of clean air when the piston again covers the inlet ports.

As the piston continues on the upward stroke, the exhaust valves close and the charge of fresh air is subjected to compression as shown in Fig. 1 (compression).

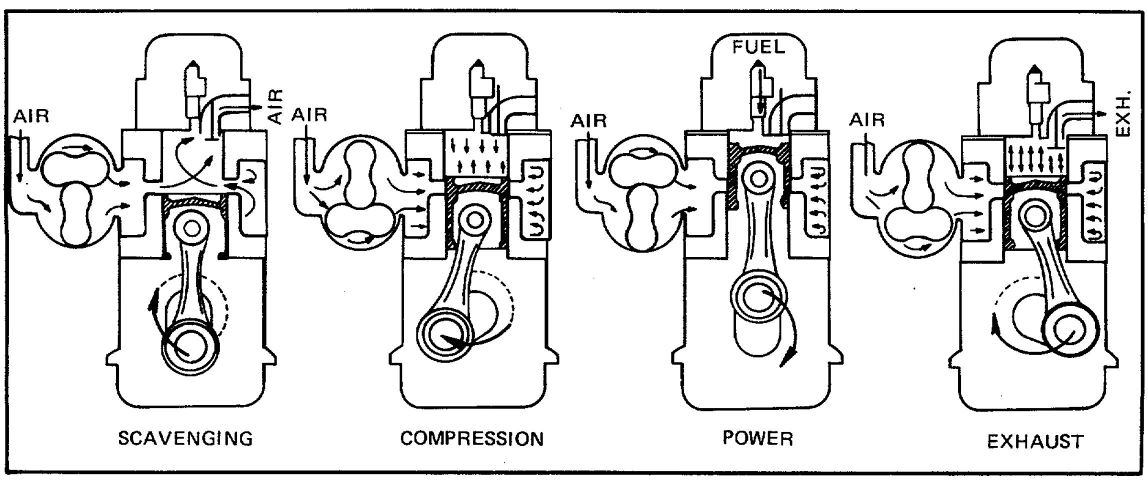


FIG. 1 - THE TWO STROKE CYCLE

Figure 1. - THE TWO STROKE CYCLE

PRINCIPLES OF OPERATION

Shortly before the piston reaches its highest position, the required amount of fuel is sprayed into the combustion chamber by the unit fuel injector as shown in Fig. 1 (power). The intense heat generated during the high compression of the air ignites the fine fuel spray immediately. The combustion continues until the injected fuel has been burned.

The resulting pressure forces the piston downward on its power stroke. The exhaust valves are again opened when the piston is about half way down, allowing the burned gases to escape into the exhaust manifold as shown in Fig. 1 (exhaust). Shortly thereafter, the downward moving piston uncovers the inlet ports and the cylinder is again swept with clean scavening air. This entire combustion cycle is completed in each cylinder for each revolution of the crankshaft, or, in other words, in two strokes; hence, it is a two-stroke cycle.

GENERAL DESCRIPTION

The two-cycle diesel engines covered in this manual have the same bore and stroke and many of the major working parts such as injectors, pistons, connecting rods, cylinder liners, and other parts are interchangeable.

The meaning of each digit in the model numbering system is shown in Fig. 2 and 3. The letter L or R indicates left- or right-hand engine rotation as viewed from the front of the engine. The letter A, B, C, or D designates the blower and exhaust manifold location on the in-line engines as viewed from the rear of the engine, while the letter A or C designates the location of the oil cooler and starter on the V-type engines.

Each engine is equipped with an oil cooler, full-flow oil filter, fuel oil strainer and fuel oil filter, an air cleaner, governor, fan and radiator, and a starting motor.

Full pressure lubrication is supplied to all main, connecting rod and cam- shaft bearings, and to other moving parts. A rotor-type pump on in-line engines draws oil from the oil pan through a screen and delivers it to the oil filter. From the filter, the oil flows to the oil cooler and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the camshaft bearings and up through the rocker arm assemblies; the remainder of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft.

Coolant is circulated through the engine by a centrifugal-type water pump. Heat is removed from the coolant, which circulates in a closed system, by the radiator. Control of the engine temperature is accomplished by thermostat(s) which regulates the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the fuel strainer by a gear- type fuel pump. It is then forced through a filter and into the fuel inlet manifold in the cylinder head and to the injectors. Excess fuel is returned to the supply tank through the fuel outlet manifold and connecting lines. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air for scavenging and combustion is supplied by a blower which pumps air into the engine cylinders via the air box and cylinder liner ports. All air entering the blower first passes through an air cleaner.

Engine starting is provided by an electric starting system. The electric starting motor is energized by a storage battery. A battery-charging generator, with a suitable voltage regulator, serves to keep the battery charged.

Engine speed is regulated by a mechanical engine governor.

GENERAL SPECIFICATIONS

	4-53
Type	2-cycle
Number of cylinders	4
Bore (inches)	3.875
Bore (mm)	98
Stroke (inches)	4.5
Stroke (mm)	114
Compression ratio (nominal--(std. engine)	17:1
Total displacement (cubic inches)	212
Total displacement (litres)	3.48
Number of main bearings	5

GENERAL DESCRIPTION

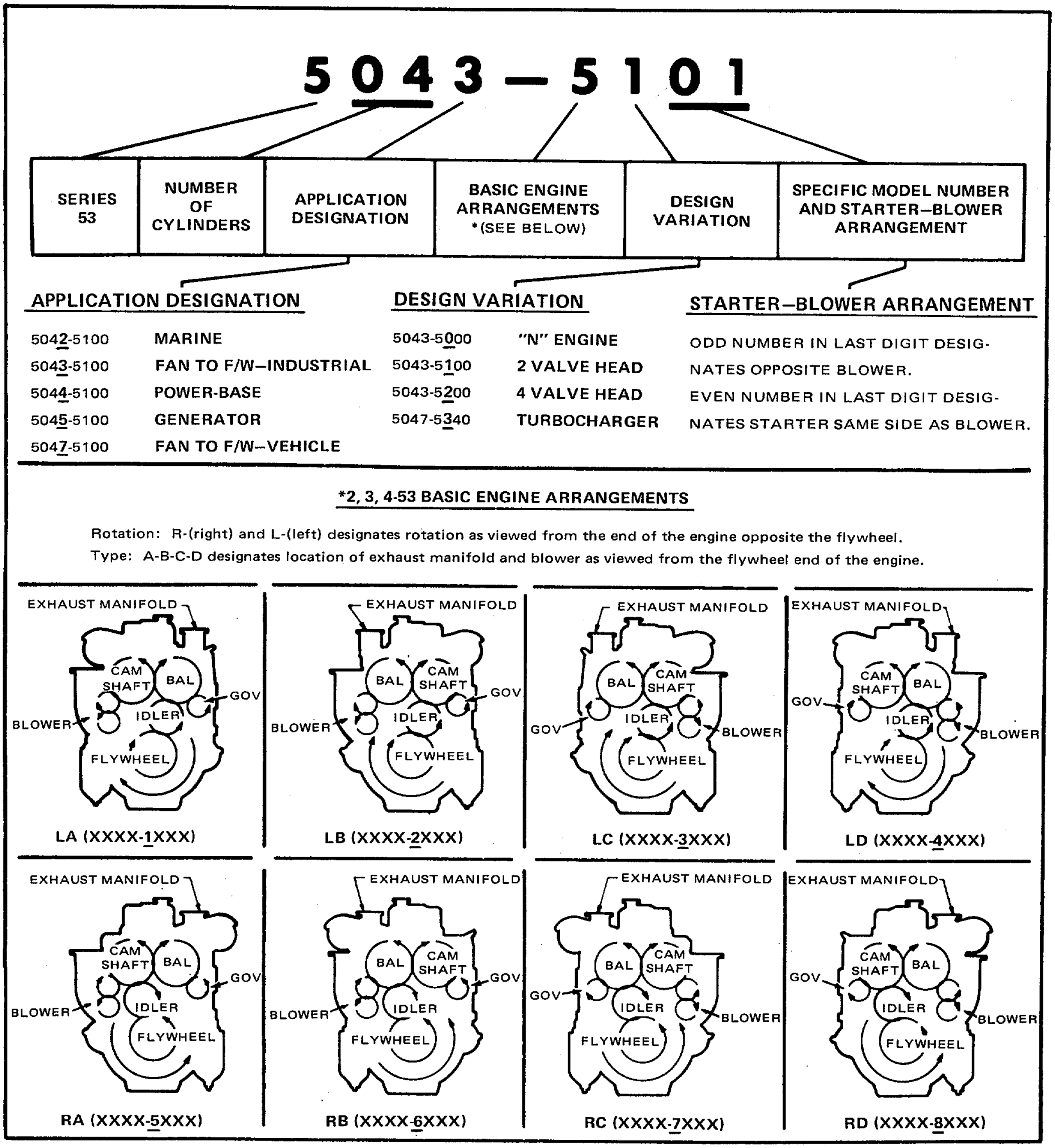


Figure 2. In-line Engine Model Description, Rotation, and Accessory Arrangements

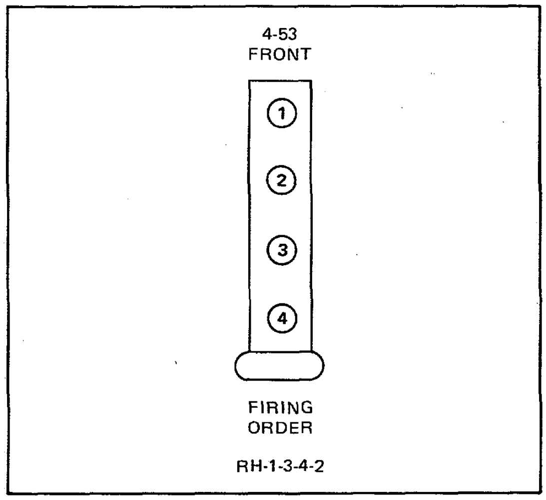


Figure 3. Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION PIATE

On the in-line engines, the model number and serial number are stamped on the right-hand side of the cylinder block in the upper rear corner (Fig. 4).

An option plate, attached to the valve rocker cover, carries the engine serial number and model number and, in addition, lists any optional equipment used on the engine (Fig. 5). Engines built in Brazil have a serial number prefix of 4DB (four-cylinder).

With any order for parts, the engine model number and serial number must be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

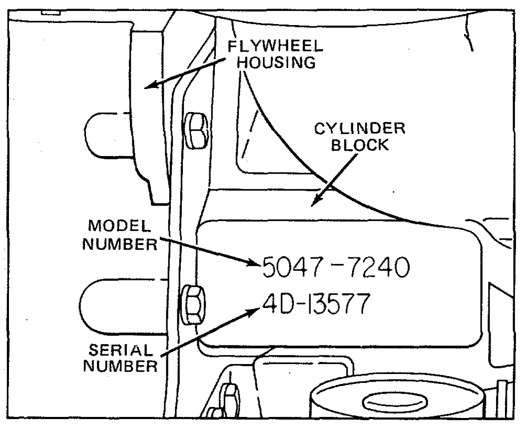


Figure 4. Typical Model and Serial Numbers as Stamped on Cylinder Block (In-Line Engine)

All groups of parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

Power takeoff assemblies, torque converters, marine gears, etc. may also carry name plates. The information on these name plates is also useful when ordering replacement parts for these assemblies.

GENERAL PROCEDURES

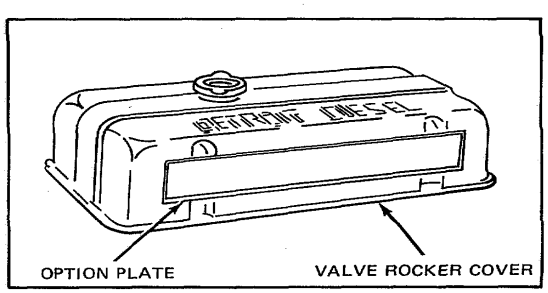


Figure 5. Option Plate

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair.

GENERAL DESCRIPTION

However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Crankshafts, cylinder liners, and other parts are in this category. For example, if a cylinder liner is only slightly worn and within usable limits, a honing operation to remove the glaze may make it suitable for reuse, thereby saving the expense of a new part. Exchange assemblies such as injectors, fuel pumps, water pumps, and blowers are also desirable service items.

Various factors such as the type of operation of the engine, hours in service, and next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble-free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

Before any major disassembly, the engine must be drained of lubricating oil, coolant, and fuel. Lubricating oil should also be drained from any transmission attached to the engine.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various subassemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly.

Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suit- able wooden racks or blocks, or a parts dolly.

CLEANING

Before removing any of the subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned. Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is outlined under *Clean Cylinder Block*, any special cleaning procedures will be mentioned in the text wherever required.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 180-200°F (82-90°C).

Fill the tank with a commercial heavy-duty solvent which is heated to the above temperature. Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all the grease and dirt.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust-preventive compound. The rust- preventive compound should be removed before installing the parts in an engine.

INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgement must be exercised by the inspector.

The guiding factors in determining the usability of worn parts, which are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize and/or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets which include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring an inspection are outside the scope of this manual. However, every shop should be equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scor- ing, chipping, and other defects.

ASSEMBLY

Following cleaning and inspection, the engine should be assembled using new parts as determined by the inspection.

Use of the proper equipment and tools makes the job progress faster and produces better results. Likewise, a suit- able working space with proper lighting must be provided. The time and money invested in providing the proper tools, equipment, and space will be repaid many times.

Keep the working space, the equipment, tools, and engine assemblies and parts clean at all times. The area where assembly operations take place should, if possible, be located away from the disassembly and cleaning operation. Also, any machining operations should be removed as far as possible from the assembly area.

Particular attention should be paid to storing of parts and subassemblies, after removal and cleaning and prior to assembly, in such a place or manner as to keep them clean. If there is any doubt as to the cleanliness of such parts, they should be recleaned.

ENGINE OVERHAUL

When assembling an engine or any part thereof, refer to the table of torque specifications at the end of each section for proper bolt, nut, and stud torques.

To ensure a clean engine at time of rebuild, it is important that any plug, fitting, or fastener (including studs) that intersects with a through hole and comes in contact with oil, fuel, or coolant must have a sealer applied to the threads.

A number of universal sealers are commercially available. It is recommended that Loctite J 26558-92 pipe sealer with teflon, or equivalent, be used.

NOTE

Certain plugs, fittings, and fasteners available from the Parts Depot already have a sealer applied to the threads. This precoating will not be affected when the pipe sealer with teflon is also applied.

IMPORTANT

The sealer information above must not be confused with International Compound No. 2, which is a lubricant applied before tightening certain bolts. Use International Compound No. 2 only where specifically stated in the manual.

WORK SAFELY

A serviceman can be severely injured if caught in the pulleys, belts, or fan of an engine that is accidentally started. To avoid such a misfortune, take these precautions before starting to work on an engine:

Disconnect the battery from the starting system by removing one or both of the battery cables. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start.

Make sure the mechanism provided at the governor for stopping the engine is in the stop position. This will mean the governor is in the no-fuel position. The possibility of the engine firing by accidentally turning the fan or, in the case of vehicle application, by being bumped by another vehicle is minimized.

WARNING

Some Safety Precautions To Observe When Working On The Engine

1. Consider the hazards of the job and wear protective gear such as safety glasses, safety shoes, hard-hat, etc. to provide adequate protection.

2. When lifting an engine, make sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

3. Always use caution when using power tools.

4. When using compressed air to clean a component, such as flushing a radiator or cleaning an air cleaner element, use a safe amount of air. Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury.

ENGINE OVERHAUL

1. Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Use perchlorethylene or trichloroethylene. However, while less toxic than other chlorinated solvents, use these cleaning agents with caution. Be sure the work area is adequately ventilated and use protective gloves, goggles or face shield, and apron.

2. Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

3. Use caution when welding on or near the fuel tank. Possible explosion could result if heat buildup inside the tank is sufficient.

4. Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

5. When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys, and belts. Avoid making contact across the two terminals of a battery, which can result in severe arcing.

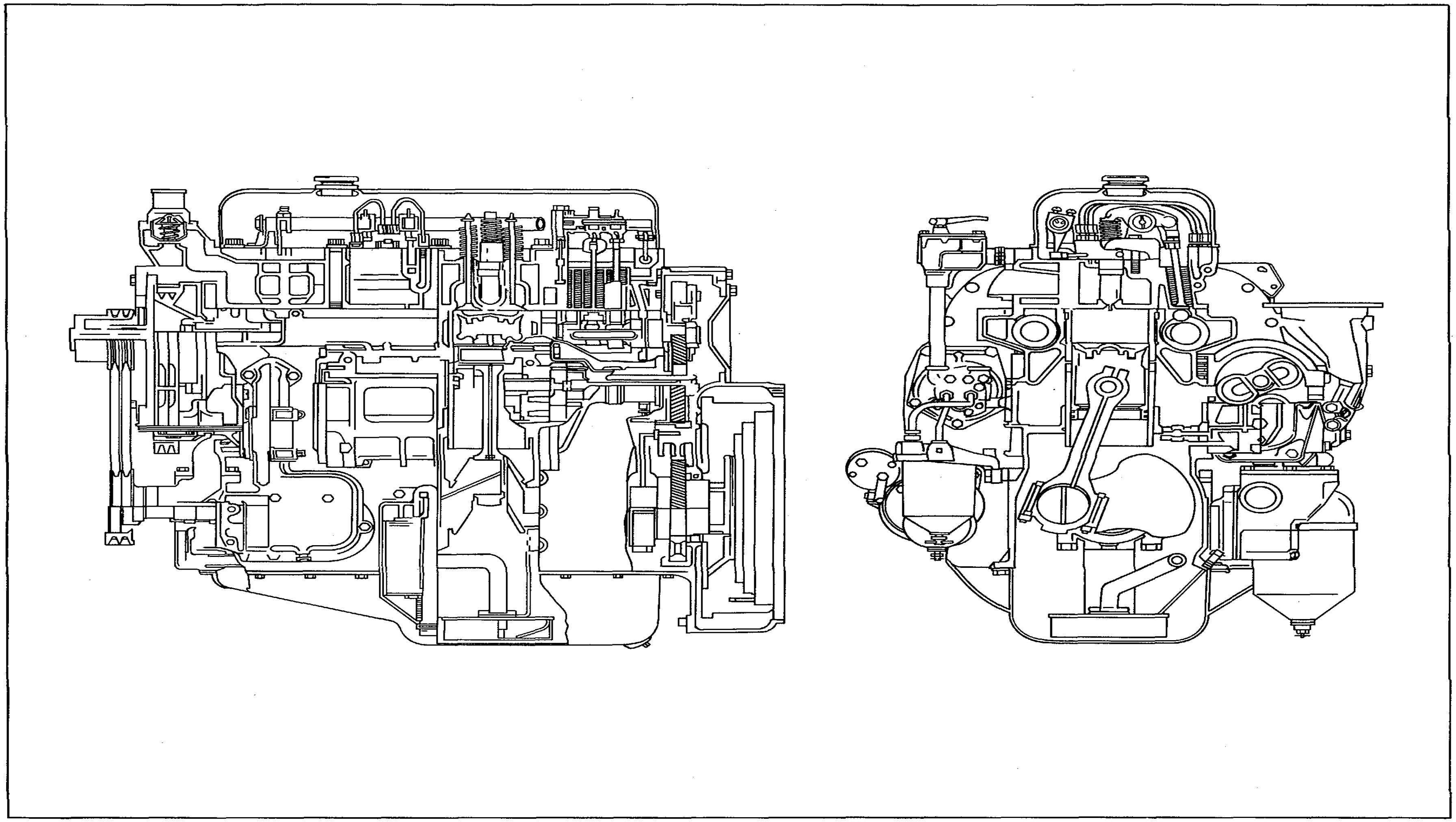


Figure 6. Cross Sections of a Typical In-Line Engine

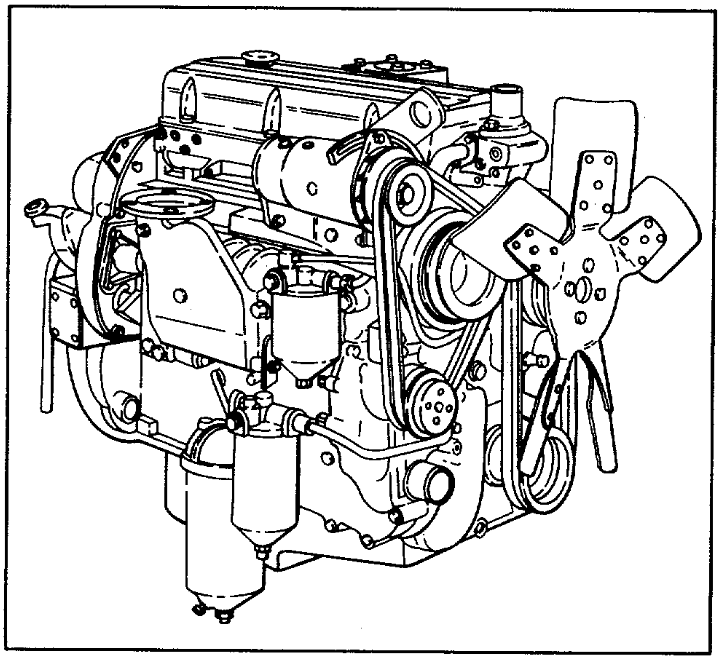


Figure 7. Typical Fan-To-Flywheel Unit (4-53)

CYLINDER BLOCK

The cylinder block (Fig. 1) serves as the main structural part of the engine. Transverse webs provide rigidity and strength, and ensure alignment of the block bores and bearings under load. Cylinder blocks for the two-, three-, and four-cylinder in-line engines are identical in design and dimensions except for length.

The block is bored to receive replaceable wet-type cylinder liners. On the in-line cast iron cylinder blocks, a water jacket surrounds the upper half of each cylinder liner. The water jacket and air box are sealed off by a seal ring compressed between the liner and a groove in the block (Fig. 2).

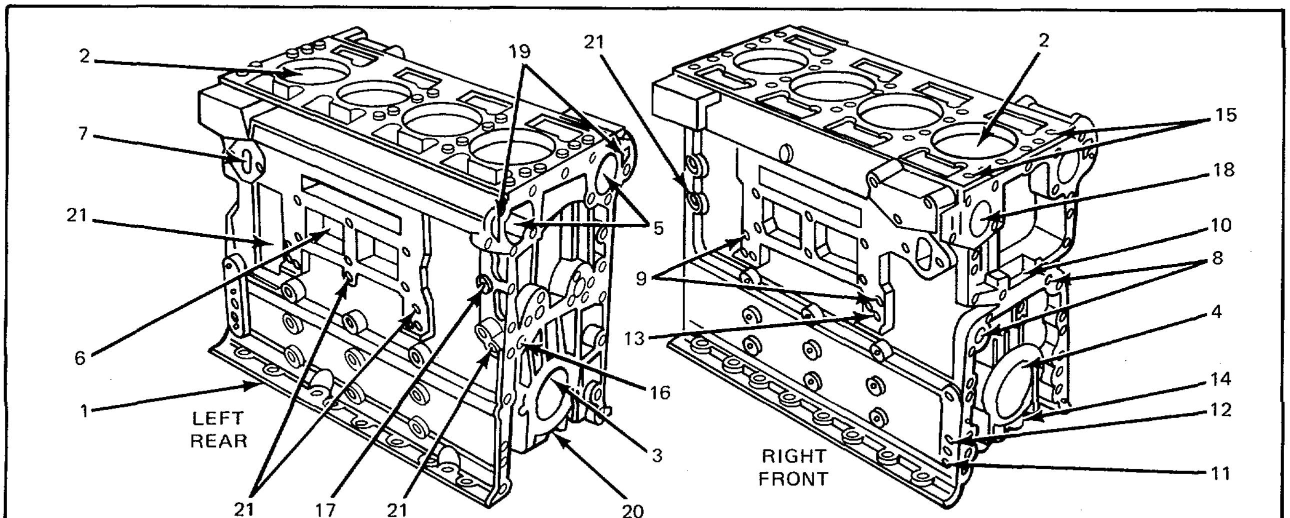
NOTE

> The current cylinder blocks have an additional seal ring groove approximately 1/8 inch below the original top groove. The lower seal ring groove in the current cylinder block has been eliminated. All turbocharged engines use a seal ring in both upper grooves.

An air box surrounding the lower half of the cylinder liners conducts the air from the blower to the air inlet ports in the cylinder liners. An opening in the side of the ,block opposite the blower on ,the in-line engines provides access to the air box and permits inspection of the pistons and compression rings through the air inlet ports in the cylinder liners.

The camshaft and balance shaft bores are located on opposite sides near the top of the in-line engine block.

The upper halves of the main bearing supports are cast integral with the block.



1. CYLINDER BLOCK
2. BORE FOR CYLINDER LINER
3. SUPPORT--UPPER MAIN BEARING (REAR)
4. SUPPORT--UPPER MAIN BEARING (FRONT)
5. BORE--CAM OR BALANCE SHAFT
6. AIR BOX
7. WATER PASSAGE FROM OIL COOLER TO BLOCK
8. OIL GALLERY (MAIN)
9. OIL GALLERY (TO BLOWER)
10. OIL DRAIN FROM FRONT COVER
11. OIL PASSAGE TO OIL COOLER
12. OIL PASSAGE FROM OIL COOLER
13. OIL DRAIN FROM BLOWER
14. CAP--MAIN BEARING (FRONT)
15. OIL PASSAGE TO CYLINDER HEAD (FROM CAMSHAFT)
16. OIL PASSAGE (IDLER GEAR BEARING)
17. WATER DRAIN
18. OIL GALLERY TO CAMSHAFT OR BALANCE SHAFT
19. OIL DRAIN FROM CYLINDER HEAD
20. CAP--MAIN BEARING (REAR)
21. OIL PRESSURE TAKE-OFF OPENING

Figure 1. Cylinder Block

ENGINE OVERHAUL

The main bearing bores are line-bored with the bearing caps in place to ensure longitudinal alignment. Drilled passages in the block carry the lubricating oil to all moving parts of the engine, eliminating the need for external piping.

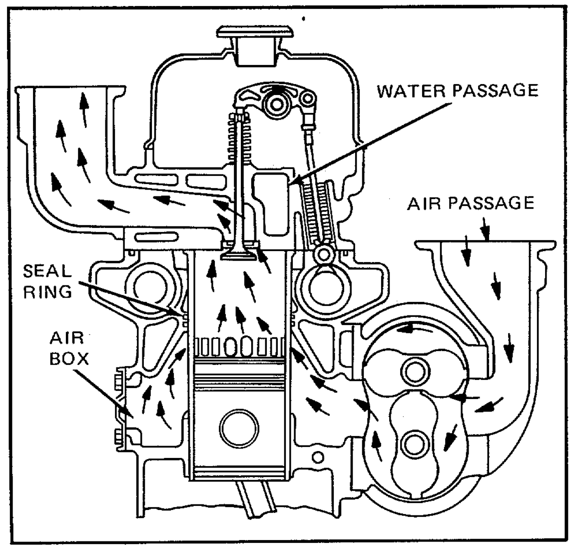


Figure 2. Air and Water Passages in In-Line Cylinder Block

The top surface of the in-line block is grooved to accommodate a block-to-head oil seal ring. Also, each water or oil hole is counterbored to provide for individual seal rings (Fig. 3).

Each cylinder liner is retained in the block by a flange at its upper end, which seats in the counterbore in the block bore. An individual compression gasket is used at each cylinder. When the cylinder head is installed, the gaskets and seal rings compress sufficiently to form a tight metal-to-metal contact between the head and the block. The in-line cylinder blocks were revised at the idler gear hub mounting pads, to increase the rigidity of the flywheel housing, by increasing two of the three 5/16-18 boltholes of each mounting pad to 3/8-16 boltholes (Fig. 4). The 3/8-16 boltholes were incorporated in engines beginning with serial number 4D-103. Revised end plates, end plate-to-block gaskets, and flywheel housing are required with the change in bolt sizes. Only the revised cylinder blocks are available for service.

The in-line cylinder blocks have also been revised to improve the breathing characteristics and increase the flow of the lubricating oil returning from the cylinder head to the engine oil sump by the addition of two vertical oil passages directly under the camshaft and balance shaft at the front end of the cylinder block (Fig. 5). Cylinder blocks with the vertical oil passages were used in engines beginning

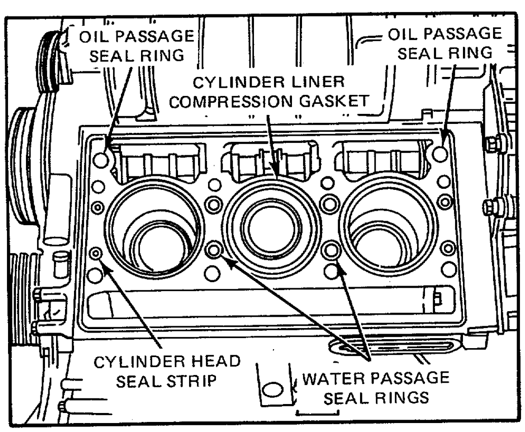


Figure 3. Cylinder Head Gaskets and Seals in Place on Cylinder Block

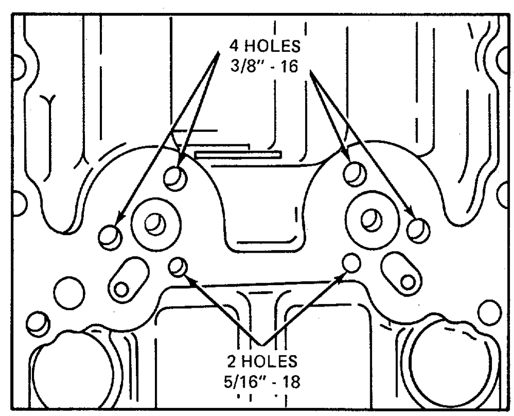


Figure 4. Location of the Four 3/8-16 Boltholes in Rear of Cylinder Block

ENGINE OVERHAUL

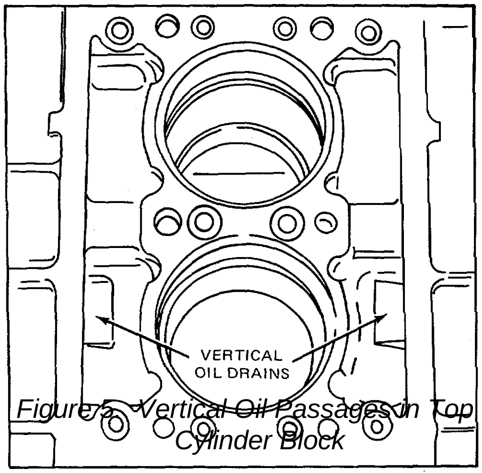


Figure 5. Vertical Oil Passages in Top of Cylinder Block

with serial numbers 2D-4010, 3D-117, and 4D-348.

New service replacement cylinder block assemblies include the main bearing caps, bolts and washers, and the camshaft bearings (bushings). The dowels and the necessary plugs are also included.

Since the cylinder block is the main structural part of the engine, the various subassemblies must be removed from the cylinder block when an engine is overhauled.

The hydraulically operated overhaul stand provides a convenient support when stripping a cylinder block. The engine is mounted in an upright position. It may then be tipped on its side, rotated in either direction (90° or 180°) where it is locked in place and then, if desired, tipped back with either end of the oil pan side up.

Remove and Disassemble Engine

Before mounting an engine on an overhaul stand, it must be removed from its base and disconnected from the transmission or other driven mechanism. Details of this procedure will vary from one application to another. However, the following steps will be necessary:

1. Drain the cooling system.

2. Drain the lubricating oil.

3. Disconnect the fuel lines.

4. Remove the air cleaner and mounting bracket.

5. Remove the blower on in-line engines.

6. Disconnect the exhaust piping and remove the exhaust manifold(s).

7. Disconnect the throttle controls.

8. Disconnect and remove the starting motor, battery-charging generator, and other electrical equipment.

9. Remove the radiator, fan guard, and other related cooling system parts.

10. Remove the air box drain tubes and fittings.

11. Remove the air box covers.

12. Disconnect any other lubricating oil lines, fuel lines, or electrical connections.

13. Separate the engine from the transmission or other driven mechanism.

14. Remove the engine mounting bolts.

15. Use a spreader bar with a suitable sling and adequate chain hoist to lift the engine from its base (Fig. 6). To prevent bending of the engine lifter brackets, the lifting device should be adjusted so the lifting hooks are vertical. To ensure proper weight distribution, all engine lifter brackets should be used to lift the engine.

CAUTION

Do not lift an engine by the webs in the air inlet opening of the cylinder block.

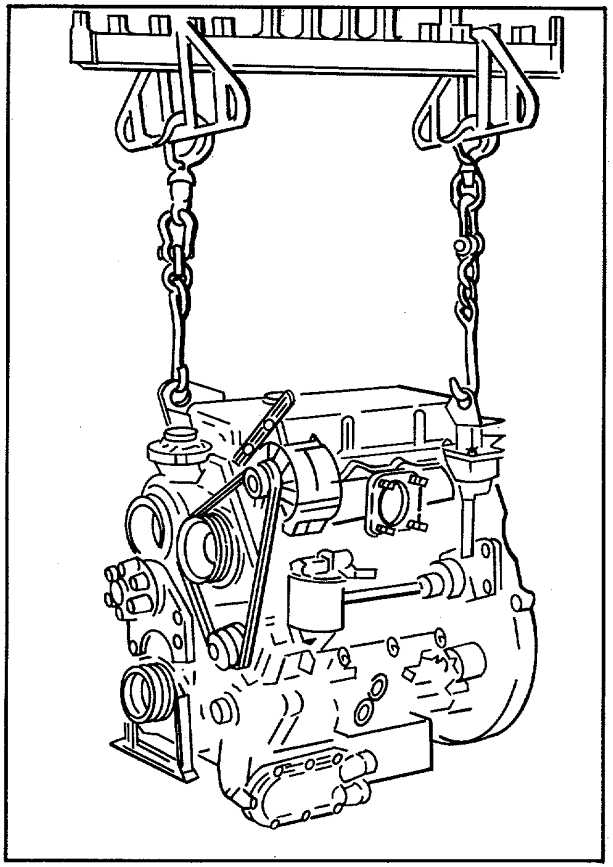


Figure 6. Lifting Engine with Spreader and Sling

16. Place the side of the cylinder block against the adaptor plate on the overhaul stand (Fig. 6). Use adaptor plate J 7622-01 (in-line engine), with overhaul stand J 6837-01.

17. Align the boltholes in the adaptor plate with the holes in the cylinder block. Then install the 3/8-16 and 5/16-18 bolts, with a flat washer under the head of each bolt, and tighten them securely.

WARNING

Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the overhaul stand.

18. With the engine mounted on the overhaul stand, remove all the remaining subassemblies and parts from the cylinder block.

The procedure for removing each subassembly from the cylinder block, together with disassembly, inspection, repair, and reassembly of each, will be found in the various sections of this manual.

After stripping, the cylinder block must be thoroughly cleaned and inspected.

Clean Cylinder Block

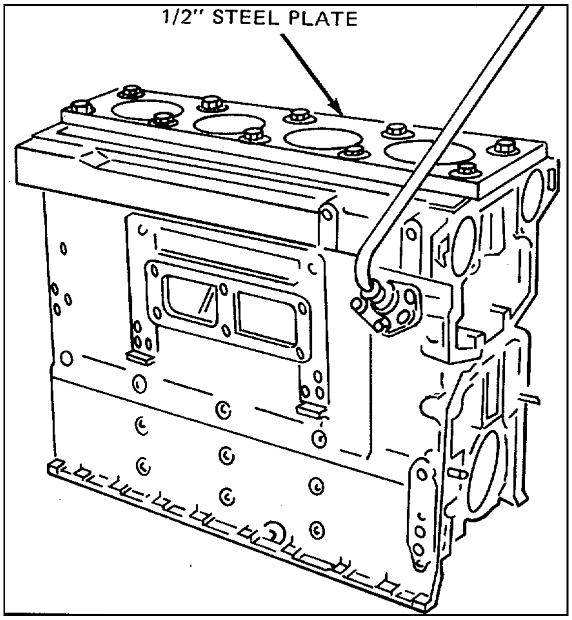
1. Remove all of the plugs (except cup plugs) and scrape all old gasket material from the block.

2. Clean the block with live steam. Make sure the oil galleries, air box floor, and air box drain openings are thoroughly cleaned. On former engines, jets machined in the camshaft and balance shaft bores (in-line engines) permit oil to be sprayed on the cam followers. Make sure they are not plugged. A 0.020 inch wire may be used to clean the jets.

3. Dry the block with compressed air.

Pressure Test Cylinder Block

After the cylinder block has been cleaned, it must be pressure tested for cracks or leaks by either one of two methods. In either method, it will be necessary to make a steel plate of 1/2-inch stock to cover each cylinder bank of the block (Fig. 7). The plate(s) will adequately seal the top surface of the block when used with cylinder liner compression gaskets and water hole seal rings. It will also be necessary to use water hole cover plates and gaskets to seal the water inlet openings in the sides of the block. One cover plate should be drilled and tapped to provide a connection for an air line so the water jacket can be pressurized.



METHOD A

This method may be used when a large enough water tank is available and the cylinder block is completely stripped of all parts.

1. Make sure the seal ring grooves in the cylinder bores of the block are clean. Then install new seal rings in the grooves (above the air inlet ports).

NOTE

The current blocks have two seal ring grooves above the air inlet ports of each cylinder bore. Only one seal ring is required, however. Install the seal ring in the upper groove, if it is in good condition; if the upper groove is pitted or eroded, install the seal ring in the lower groove.

2. Apply a light coating of hydrogenated vegetable-type shortening or permanent-type antifreeze solution to the seal rings.

3. Slide the cylinder liners into the block, being careful not to roll or damage the seal rings. Install new compression gaskets and water hole seal rings in the counterbores in the top surface of the block.

4. Secure the plate(s) on the top of the block with 5/8-11 bolts and flat washers.

5. Install the water hole cover plates and gaskets on the sides of the block.

6. Immerse the cylinder block for twenty minutes in a tank of water heated to 180-200°F (82-93°C).

7. Attach an air line to the water hole cover plate and apply 40 psi (276 kPa) air pressure to the water jackets and observe the water in the tank for bubbles which will indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

8. Remove the block from the water tank. Then remove the plates, seals, gaskets, and liners and blow out all of the passages in the block with compressed air.

9. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

ENGINE OVERHAUL

METHOD B

This method may be used when a large water tank is unavailable, or when it is desired to check the block for cracks without removing the engine from the equipment which it powers. However, it is necessary to remove the cylinder head(s), blower, oil cooler, air box covers, and oil pan.

1. Prepare the block as outlined in Method A. However, before installing the large sealing plate, fill the water jacket with a mixture of water and one gallon of permanent-type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.

2. Install the plate(s) and water hole covers as outlined in Method A.

3. Apply 40 psi (276 kPa) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

4. At the end of this test period, examine the cylinder bores, air box, oil passages, crankcase, and exterior of the block for presence of the water and antifreeze mixture, which will indicate the presence of cracks. A cracked cylinder block must be replaced by a new block.

5. After the pressure test is completed, remove the plates and drain the water jacket. Then remove the liners and seal rings and blow out all the passages in the block with compressed air.

6. Dry the cylinder liners with compressed air and coat them with oil to prevent rust.

Inspect Cylinder Block

After cleaning and pressure testing, inspect the cylinder block.

1. Check the block bores as follows:

a. Make sure the seal ring grooves (Fig. 8) are thoroughly clean. Then inspect the grooves and lands for evidence of pitting and erosion. Two grooves are provided above the air inlet ports of each cylinder bore in the current block. The single groove formerly below the air inlet ports has been eliminated. However, a cylinder liner seal ring is required in the upper groove only. The lower groove (on the current block) is provided for the seal ring if inspection reveals extensive pitting or erosion along the upper land or inner surface of the upper groove. If both grooves are eroded to the extent that sealing is affected, then the block must be replaced.

b. Measure the entire bore of each cylinder with cylinder bore gage J 5347-01 (Fig. 9) which has a dial indicator calibrated in 0.0001 inch increments. Use dial bore gage setting tool Figure 8. Location of Block Bore Seal Ring Groove

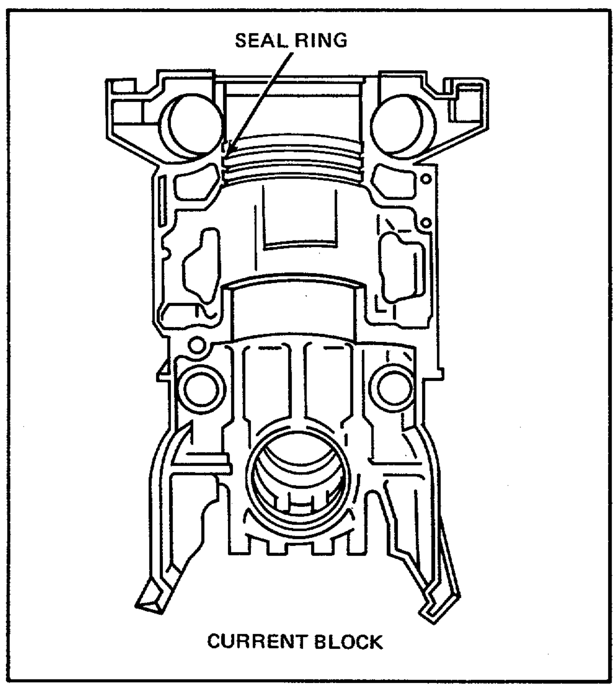


Figure 8. Location of Block Bore Seal Ring Groove

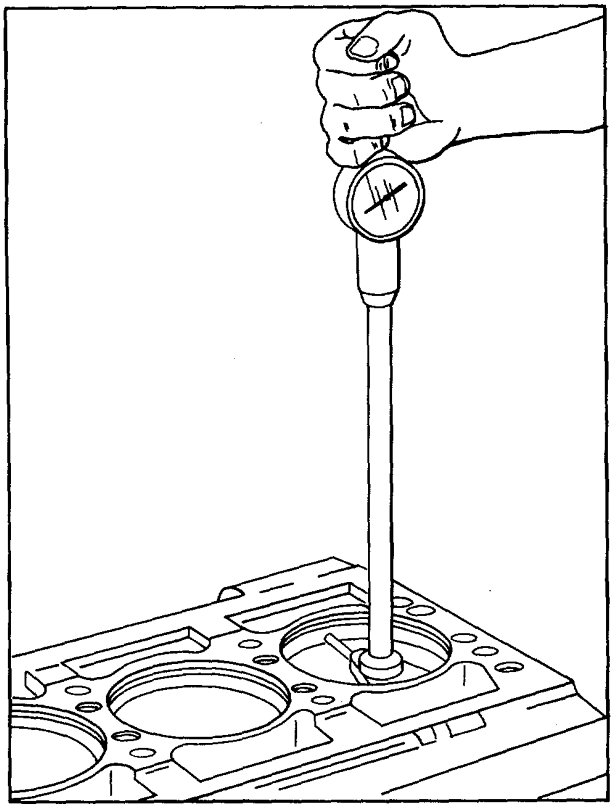


Figure 9. Checking Cylinder Block Bore with Tool J 5347-01

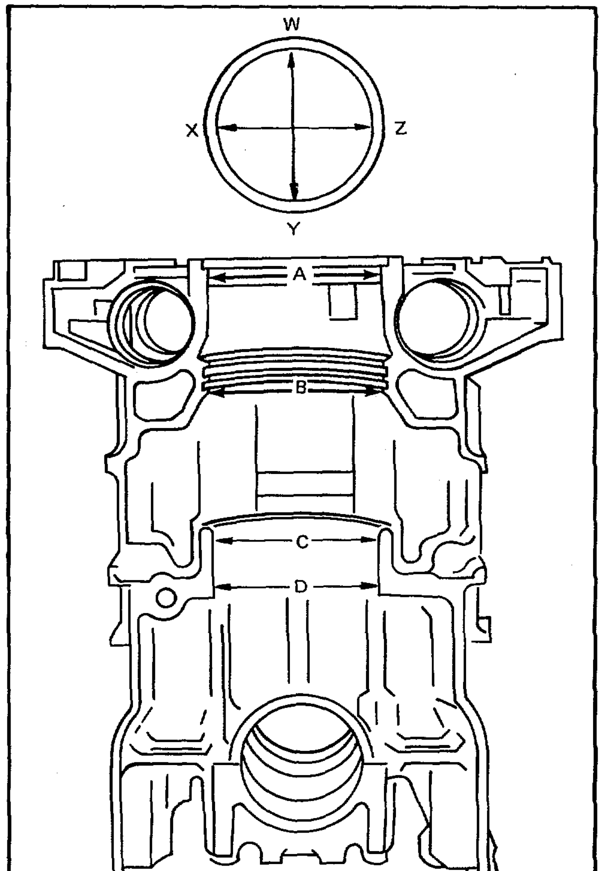


Figure 10. Block Bore Measurement Diagram

J 23059-01 to preset the cylinder bore gage to zero. Measure each block bore at the positions indicated in Fig. 10, on axis 90° apart. If the diameter does not exceed 4.5235 inches at position A, 4.4900 inches at position B (and a sealing problem hasn't occurred), or 4.3595 inches at position C and D, then the block may be reused. Also, the taper and out of round must not exceed 0.0015 inch.

2. Check the top of the block for flatness with an accurate straight edge and a feeler gage. The top surface must not vary more than 0.003 inch transversely and not over 0.007 inch longitudinally.

3. Make sure the cylinder liner counterbores in the block are clean and free of dirt. Then check the depth. The depth must be 0.300 to 0.302 inch and must not vary more than 0.0015 inch throughout the entire circumference. The counterbored surfaces must be smooth and square with the cylinder bore within 0.001 inch total indicator reading. There must not be over 0.001

inch difference between any two adjacent cylinder counterbores when measured along the cylinder longitudinal centerline of the cylinder block.

4. Check the main bearing bores as follows:

a. Check the bore diameters with the main bearing caps in their original positions. Lubricate the bolt threads and bolt head contact areas with a small quantity of International Compound No. 2, or equivalent. Then install and tighten the bolts to the specified torque. When making this check, do not install the main bearing cap stabilizers. The specified bore diameter is 3.251 to 3.252 inches. If the bores do not fall within these limits, the cylinder block must be rejected.

CAUTION

Main bearing cap bolts are especially designed for this purpose and must not be replaced by ordinary bolts. Effective with engine serial numbers 6D-27030 and 8D-1155, a new hexagon head bolt and hardened steel washer are being used in place of the former 12-point flange-type main bearing cap bolt.

CAUTION

Bearing caps are numbered to correspond with their respective positions in the cylinder block. It is imperative that the bearing caps are reinstalled in their original positions to maintain the main bearing bore alignment. The number of the front main bearing cap is also stamped on the face of the oil pan mounting flange of the cylinder block, adjacent to its permanent location in the engine as established at the time of manufacture. The No. 1 main bearing cap is always located at the end opposite the flywheel end of the cylinder block (Fig. 11).

b. Finished and unfinished main bearing caps are available for replacing broken or damaged caps. When fitting a finished replacement bearing cap, it may be necessary to try several caps before one will be found to provide the correct bore diameter and bore alignment. If a replacement bearing cap is installed, be sure to stamp the correct bearing position number on the cap.

CAUTION

Use the unfinished bearing caps for the front and intermediate bearing positions. The finished bearing caps, machined for the crankshaft thrust washers, are to be used in the rear bearing position.

c. Main bearing bores are linebored with the bearing caps in place and thus are in longitudinal alignment. Bearing bores may be considered properly aligned with one another if the crankshaft can be rotated freely by hand after new bearing shells have been installed and lubricated, the bearing

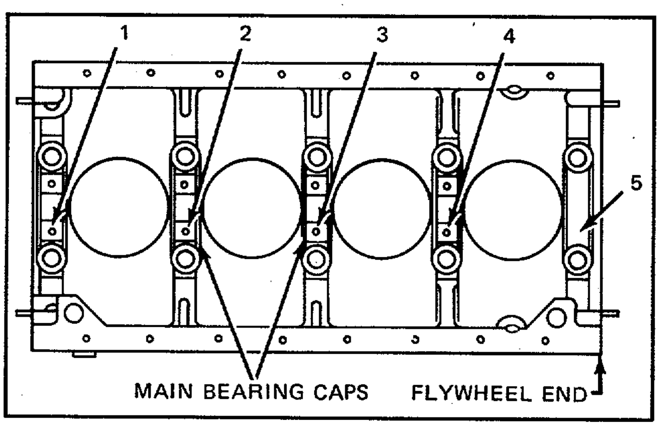


Figure 11. Typical Cylinder Block Markings

caps have been secured in place, and the bolts tightened to the specified torque. If a main bearing bore is more than 0.001 inch out of alignment, the block must be line-bored or scrapped. Misalignment may be caused by a broken crankshaft, excessive heat, or other damage.

d. If the main bearing bores are not in alignment when a replacement bearing cap is used, the block must be line-bored. Install the bearing caps in their original positions (without the bearing cap stabilizers) and tighten the bolts to the specified torque (*Specifications*). Line-bore the block, but do not remove more than O.001 inch stock. After boring, all bores must be within the specified limits of 3.251 to 3.252 inches.

5. Refer to the *Cylinder Block Plugging Charts* shown as a fold out at the end of this manual and install the necessary plugs and dowels.

6. Replace loose or damaged dowel pins. The dowels at the ends of the cylinder block must extend 0.680 inch from the cylinder block face.

The dowels used to retain the crankshaft thrust washers on the rear main bearing cap must extend 0.107 to 0.117 inch from the surface of the bearing cap.

NOTE

A stepped dowel pin is available to replace loose pins in the rear main bearing cap. Before installing the stepped pins, rebore the dowel holes in the bearing cap with a No. 11 (0.1910 inch) or No. 12 (0.1890 inch) drill. After pressing the pins into the bearing cap, remove all burrs from the base of the dowel pins to ensure proper seating of the thrust washers.

7. Check all of the machined surfaces and threaded holes in the block. Remove nicks and burrs from the machined surfaces with a file. Clean up damaged threads in tapped holes with a tap or install helical thread inserts.

8. After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil. If the block is to be stored for an extended period of time, spray or dip it in a polar-type rust preventive such as Valvoline Oil Company's Tectyl 502-C, or equivalent. Castings free of grease or oil will rust when exposed to the atmosphere.

Assemble and Install Engine

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

CAUTION

Before a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.

1. Mount the block on the overhaul stand.

2. If a new service replacement block is used, stamp the engine serial number and model number on the upper rear corner of the in-line block. Also stamp the position numbers on the main bearing caps (Fig. 11) and the position of the No. 1 bearing on the oil pan mounting flange of the block.

3. Install all the required plugs and drain cocks. Use a good grade of nonhardening sealant on the threads of the plugs and drain cocks. If a new service replacement block is used, make sure the top surface is plugged correctly to prevent low oil pressure or the accumulation of abnormal quantities of oil in the cylinder head.

ENGINE OVERHAUL

4. Clean and inspect all of the engine parts and subassemblies and, using new parts as required, install them on the cylinder block by reversing the sequence of disassembly. The procedures for inspecting and installing the various parts and subassemblies are outlined in the following sections of this manual.

5. Use a chain hoist and suitable sling to transfer the engine to a dynamometer test stand.

6. Install the air box covers and tighten the bolts. On in-line engines,tighten the bolts to 12-16 lb ft (16-22 Nm) torque.

7. Complete the engine buildup by installing all remaining accessories, fuel lines, electrical connections, controls, etc.

8. Operate the engine on a dynamometer, following the run-in procedure outlined in *Run-In Instructions.*

9. Reinstall the engine in the equipment which it powers.

CYLINDER BLOCK END PLATE

A flat steel plate, bolted to the rear end of the cylinder block, provides a support for the flywheel housing. A gasket is used between the block and the end plate.

Inspection

When the end plate is removed, it is essential that all of the old gasket material be removed from both surfaces of the end plate and the cylinder block. Clean the end plate as outlined under *Clean Cylinder Block*.

Inspect both surfaces of the end plate for nicks, dents, scratches, or score marks and check it for warpage. Check the plug nuts in the end plate for cracks or damaged threads. If nicks or scratches on the sealing surfaces of the end plate are too deep to be cleaned up, or the plug nuts are damaged, replace the end plate or plug nuts.

When installing a plug nut, support the end plate on a solid flat surface to avoid distorting the plate. Then press the nut in the end plate until the head on the nut seats on the end plate.

Install End Plate

1. Affix a new gasket to the end of the cylinder block (flywheel end), using a nonhardening gasket cement. Also apply an even coating of gasket cement to the outer surface of the gasket (the surface next to the end plate).

2. Align the dowel pinholes in the end plate with the dowel pins in the cylinder block. Then start the end plate over the dowel pins and push it up against the cylinder block.

CAUTION

When installing the end plate, the heads of the plug nuts at the top of the end plate on the in-line engine should always face the forward end of the cylinder block.

3. On in-line engines, refer to Fig. 1 and install the 3/8-16 x 7/8 inch long bolts with lockwashers. Tighten the bolts to 30-35 lb ft (41-47 Nm) torque.

CAUTION

On in-line engines built prior to engine serial numbers 2D-903, 3D-011, and 4D-103, the top center end plate attaching bolt was 3/8-16 x 3/4 inch long. Do not use a longer bolt at this location on engines built prior to the above engine serial numbers.

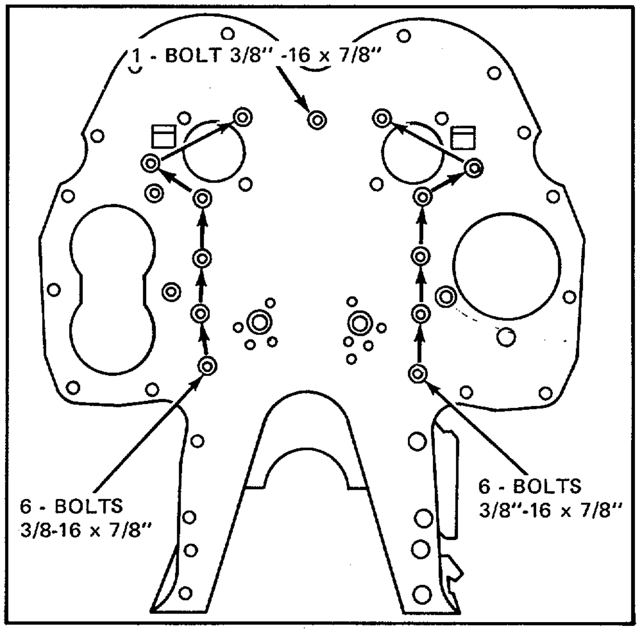


Figure 1. Cylinder Block Rear End Plate Mounting (In-Line Engine)

ENGINE OVERHAUL

During normal engine operation, water vapor from the air charge, as well as a slight amount of fuel and lubricating oil fumes, condenses and settles on the bottom of the air box. This condensation is removed by the air box pressure through air box drain tubes mounted on the sides of the cylinder block.

The air box drains must be kept open at all times, otherwise water and oil that may accumulate will be drawn into the cylinders.

One drain tube is used on an in-line engine (Fig. 1) at the rear end of the cylinder block.

Inspection

A periodic check for air flow from the air box drain tubes should be made (refer to *Preventive Maintenance*)

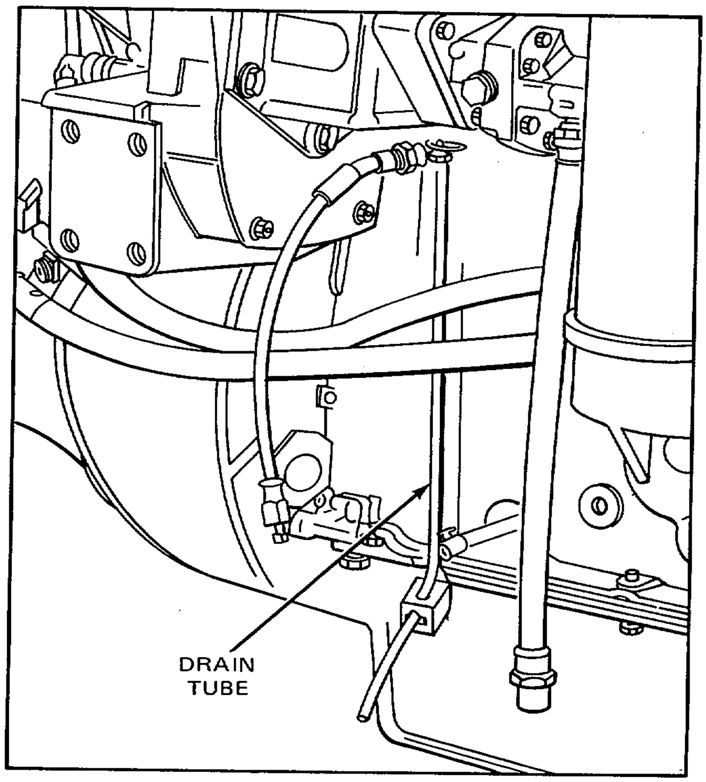


Figure 1. Air Box Drain Tube Mounting (In-Line Engines)

ENGINE OVERHAUL

CYLINDER HEAD

The cylinder head (Fig. 1) is a one-piece casting securely held to the top of the cylinder block by special bolts.

The exhaust valves, fuel injectors, and the valve and injector operating mechanism are located in the cylinder head. Depending upon the engine application, either two or four exhaust valves are provided for each cylinder.

Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of valves under varying conditions of temperature and materially prolong the life of the cylinder head.

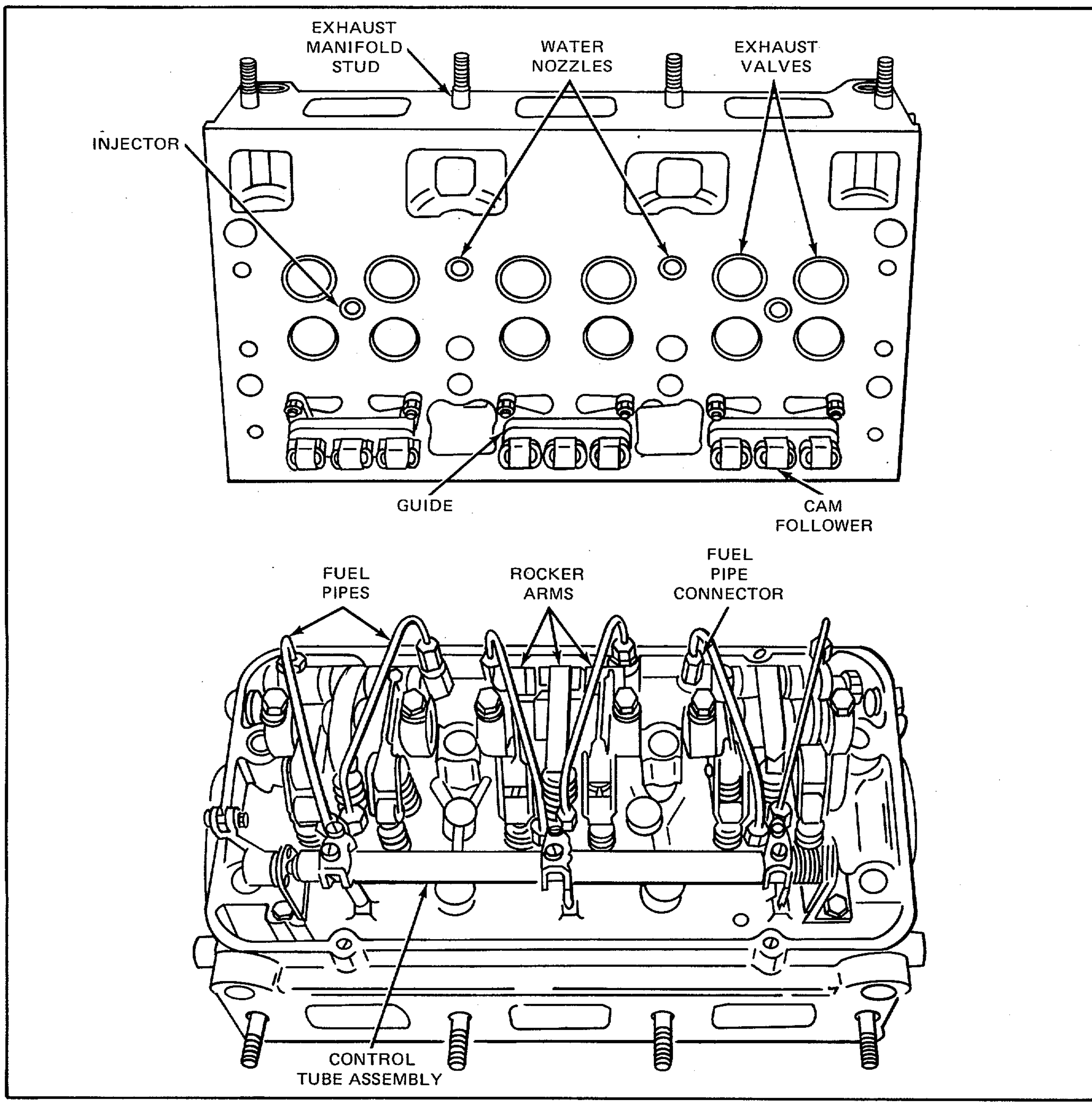


Figure 1. Typical Four-Valve Cylinder Head

ENGINE OVERHAUL

To ensure efficient cooling, each fuel injector is inserted into a thin-walled tube which passes through the water space in the cylinder head. The lower end of the injector tube is pressed into the cylinder head and flared over; the upper end is flanged and sealed with a neoprene seal. The sealed upper end and flared lower end of the injector tube prevent water and compression leaks.

The exhaust passages from the exhaust valves of each cylinder lead through a single port to the exhaust manifold. The exhaust passages and the injector tubes are surrounded by engine coolant.

In addition, cooling of the above areas is further ensured by the use of water nozzles pressed into the water inlet ports in the four-valve cylinder head. The nozzles direct the comparatively cool engine coolant at high velocity toward the sections of the cylinder head which are subjected to the greatest heat. The coolant flow pattern in the two-valve cylinder head is such that nozzles are not required.

The fuel inlet and outlet manifolds are cast as an integral part of the cylinder head. Tapped holes are provided for connection of the fuel lines at various points along each manifold.

To seal compression between the cylinder head and the cylinder liner, separate laminated metal gaskets are provided at each cylinder. Water and oil passages between the cylinder head and cylinder block are sealed with synthetic rubber seal rings which fit into the counterbored holes in the block. A synthetic rubber seal fits into a milled groove near the perimeter of the block. When the cylinder head is drawn down, a positive leakproof metal-to-metal contact is assured between the head and the block.

The engine operating temperature should be maintained between 160-185°F or 71-85°C and the cooling system should be inspected daily and kept full at all times. The cylinder head fire deck will overheat and crack in a short time if the coolant does not cover the fire deck surface. When necessary, add water slowly to a hot engine to avoid rapid cooling which can result in distortion and cracking of the cylinder head (and cylinder block).

Abnormal operating conditions or neglect of certain maintenance items may cause cracks to develop in the cylinder head. If this type of failure occurs, a careful inspection should be made to find the cause and avoid a recurrence of the failure.

Unsuitable water in the cooling system may result in lime and scale formation and prevent proper cooling. The cylinder head should be inspected around the exhaust valve water jackets. This can be done by removing an injector tube. Where inspection discloses such deposits, use a reliable noncorrosive scale remover to remove the deposits from the cooling system of the engine, since a similar condition will exist in the cylinder block and other components of the engine. Refer to Coolant Specifications.

Loose or improperly seated injector tubes may result in compression leaks into the cooling system and also result in loss of engine coolant. The tubes must be tight to be properly seated. Refer to Injector Tube.

Overtightened injector clamp bolts may also cause head cracks. Always use a torque wrench to tighten the bolts to the specified torque.

Other conditions which may eventually result in cylinder head cracks are as follows:

1. Excess fuel in the cylinders caused by leaking injectors.

2. Slipping fan belts can cause overheating by reducing air flow through the radiator.

3. Accumulation of dirt on the radiator core which will reduce the flow of air and slow the transfer of heat from the coolant to the air.

4. Inoperative radiator cap which will result in loss of coolant.

Remove Cylinder Head

The following service operations on the engine require removal of the cylinder head:

1. Remove and install pistons.

2. Remove and install cylinder liners.

3. Remove and install exhaust valves.

4. Remove and install exhaust valve guides.

5. Recondition exhaust valves and valve seat inserts.

6. Replace fuel injector tubes.

7. Install new cylinder head gaskets and seals.

8. Remove and install camshaft.

Due to the various optional and accessory equipment used, only the general steps for removal of the cylinder head are covered. If the engine is equipped with accessories that affect cylinder head removal, note the position of each before disconnecting or removing them to ensure correct reinstallation. Then remove the cylinder head as follows:

1. Drain the cooling system.

2. Disconnect the exhaust piping at the exhaust manifold.

3. Remove the air cleaners or air silencer.

4. Disconnect the fuel lines at the cylinder head.

5. Remove the thermostat housing and the thermostat as an assembly.

6. Clean and remove the valve rocker cover and the governor cover.

7. Disconnect and remove the fuel rod between the governor and the injector control tube lever. Remove the fuel rod cover, if used.

8. Remove the exhaust manifold.

9. Remove the injector control tube and brackets as an assembly.

10. If the cylinder head is to be disassembled for reconditioning of the exhaust valves and valve seat inserts or for a complete overhaul, remove the fuel pipes and injectors at this time. Refer to Fuel Injector for removal of the injectors.

11. Check the torque on the cylinder head bolts before removing the head. Then remove the bolts and lift the cylinder head from the cylinder block using tool J 22062-01 (Fig. 2). Checking the torque before removing the head bolts and examining the condition of the compression gaskets and seals after the head is removed may reveal the causes of any cylinder head problems.

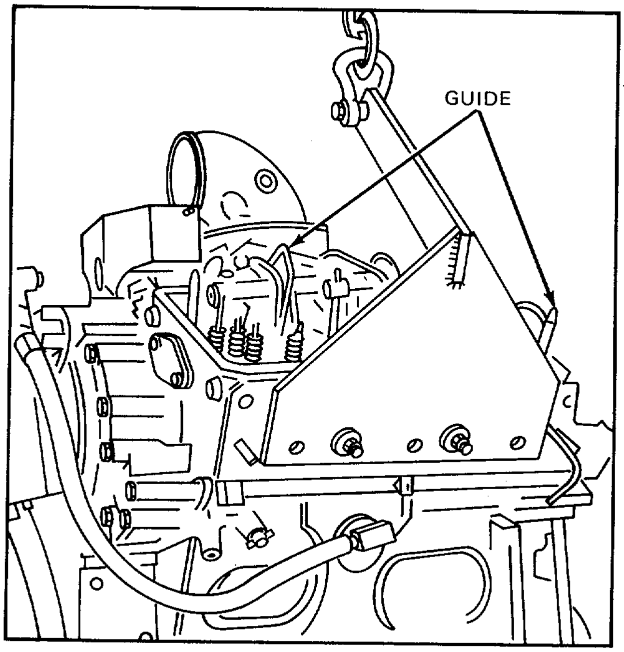


Figure 2. Lifting or Installing Cylinder Head with Tool J 22062-01

CAUTION

When placing the cylinder head assembly on a bench, protect the cam followers and injector spray tips, if the injectors were not removed, by resting the valve side of the head on 2-inch thick woodblocks.

12. Remove and discard the cylinder head compression gaskets, oil seals, and water seals.

13. After the cylinder head has been removed, drain the lubricating oil from the engine. Draining the oil at this time will remove any coolant that may have worked its way to the oil pan when the head was removed.

Disassemble Cylinder Head

If complete disassembly of the cylinder head is necessary, refer to Valve Operating Mechanism and Exhaust Valves for removal of the exhaust valve and injector operating mechanism.

After the cylinder head has been disassembled and all the plugs (except cup plugs) have been removed, thoroughly steam clean the head. If the water passages are heavily coated with scale, remove the injector tubes and water nozzles. Then clean the cylinder head in the same manner as outlined for cleaning the cylinder block (Cylinder Block).

Clean all cylinder components with fuel oil and dry them with compressed air.

Inspect Cylinder Head

1. Before a cylinder head can be reused, it must be inspected for cracks. Five prescribed methods for checking a cylinder head for cracks are as follows:

CAUTION

If any method reveals cracks, the cylinder head should be considered unacceptable for reuse.

Magnetic Particle Method: The cylinder head is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which cause the magnetic particles in the powder or solution to gather there, effectively marking the crack. The cylinder head must be demagnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under a black light. Very fine cracks that may be missed using the first method, especially on discolored or dark surfaces, will be disclosed under the black light.

ENGINE OVERHAUL

Fluorescent Penetrant Method: A highly fluorescent liquid penetrant is applied to the area in question. Then the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection to find the crack is carried out using a black light.

Nonfluorescent Penetrant Method: The test area being inspected is sprayed with Spot-check or Dye Check. Allow 1 to 30 minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with cleaner/ remover. DO NOT flush surface with cleaner/remover because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then spray this developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

NOTE

The above four methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

Pressure Check Method: Pressure check the cylinder head as follows:

a. Seal off the water holes in the head with steel plates and suitable rubber gaskets secured in place with bolts and washers. Drill and tap one of the cover plates for an air hose connection.

b. Install scrap or dummy injectors to ensure proper seating of the injector tubes. Dummy injectors may be made from old injector nuts and bodies the injector spray tips are not necessary. Tighten the injector clamp bolts to 20-25 lb ft (27-34 Nm) torque.

c. Apply 40 psi (276 kPa) air pressure to the water jacket. Then immerse the cylinder head in a tank of water, previously heating to 180-200°F or 82-930 C, for about 20 minutes to thoroughly heat the head. Observe the water in the tank for bubbles, which indicate a leak or crack. Check for leaks at the top and bottom of the injector tubes, oil gallery, exhaust ports, fuel manifolds, and the top or bottom of the cylinder head.

d. Relieve the air pressure and remove the cylinder head from the water tank. Then remove the plates, gaskets, and injectors and dry the head with compressed air.

e. If the pressure check revealed any cracks, install a new cylinder head.

2. Check the bottom (fire deck) of the cylinder head for flatness as follows:

a. Use a heavy, accurate straightedge and feeler gages, tool J 3172, to check for transverse warpage at each end and between all cylinders. Also check for longitudinal warpage in six places as shown in Fig. 3. Refer to Table 1 for maximum allowable warpage.

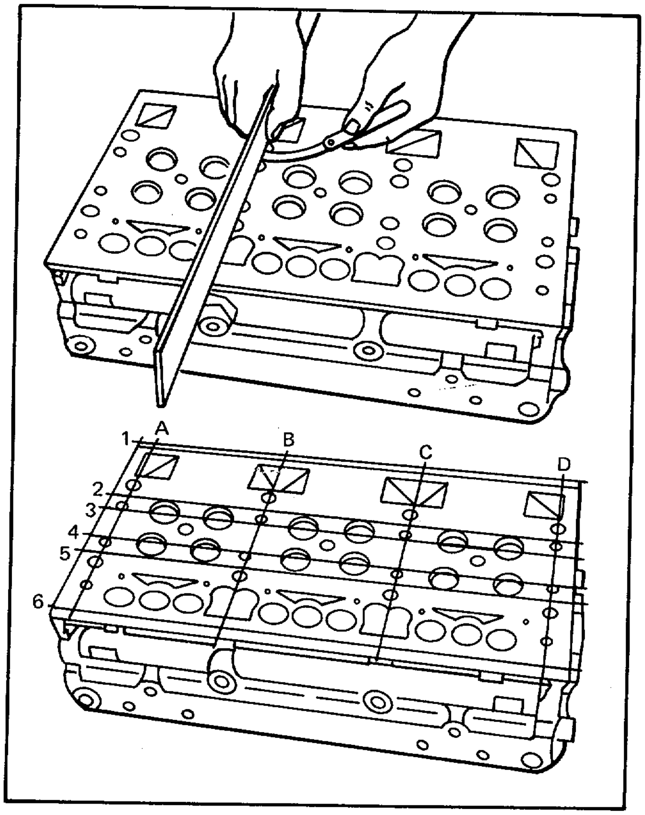


Figure 3. Checking Bottom Face of Cylinder Head for Warpage

Engine	Maximum Longitudinal Warpage	Maximum Transverse Warpage
2-53	0.004-inch	0.004-inch
3-53, 6V-53	0.005-inch	0.004-inch
4-53, 8V-53	0.006-inch	0.004-inch

TABLE 1

b. Use the measurements obtained and the limits given in Table 1 as a guide to determine the advisability of reinstalling the head on the engine or of refacing it. The number of times a cylinder head may be refaced will depend upon the amount of stock previously removed.

c. If the head is to be refaced, remove the injector tubes prior to machining. Do not remove more metal from the fire deck of any cylinder head below the minimum distance of 4.376 inches (Fig. 4).

CAUTION

When a cylinder head has been refaced, critical dimensions such as the protrusion of valve seat inserts, exhaust valves, injector tubes, and injector spray tips must be checked and corrected. The push rods must also be adjusted to prevent the exhaust valves from striking the pistons after the cylinder head is reinstalled in the engine.

3. Install new injector tubes (Injector Tube) if the old tubes leaked or the cylinder head was refaced.

4. Inspect the exhaust valve seat inserts and valve guides (Exhaust Valves).

5. Inspect the cam follower bores in the cylinder head for scoring or wear. Light score marks may be cleaned up with crocus cloth wet with fuel oil. Measure the bore diameters with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record and compare the readings of the followers and bores to determine the cam follower-to-bore clearances. The clearance must not exceed 0.006-inch with used parts (refer to Specifications). If the bores are excessively scored or worn, replace the cylinder head.

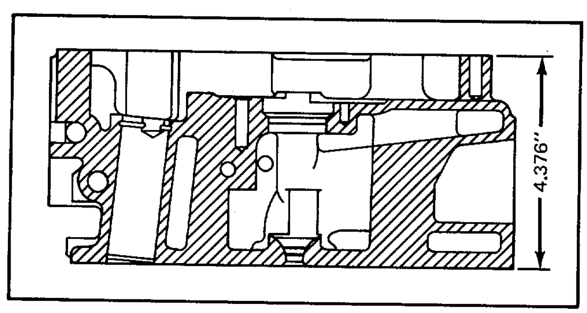


Figure 4. Minimum Distance Between Top and Bottom Faces of Cylinder Head

6. Check the water hole nozzles (four-valve head only) to be sure they are not loose. If necessary, replace the nozzles as follows:

a. Remove the old nozzles.

b. Make sure the water inlet ports in the cylinder head are clean and free of scale. The water holes may be cleaned up with a 5/8-inch drill. Break the edges of the holes slightly.

c. Press the nozzles in place with the nozzle openings positioned as shown in Fig. 5. Press the nozzles flush to 0.0312-inch recessed below the surface of the cylinder head.

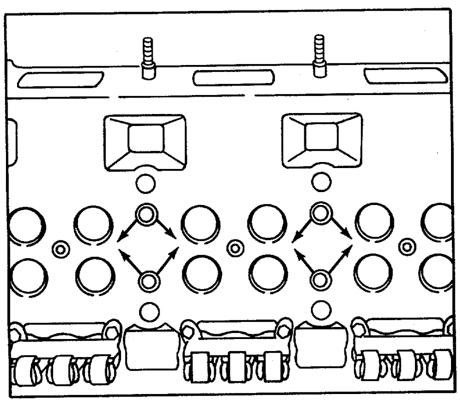


Figure 5. Correct Installation of Water Nozzles in Four-Valve Cylinder Head

d. Check to make sure the nozzles fit tight. If necessary, use a wood plug or other suitable tool to expand the nozzles, or tin the outside diameter with solder to provide a tight fit. If solder is used, make sure the orifices in the nozzles are not closed with solder. Figure 5. Correct Installation of Water Nozzles in Four-Valve Cylinder Head

7. Replace broken or damaged exhaust manifold studs. Apply sealant to the threads and drive new studs to 25-40 lb ft (34-54 Nm) torque (1.40-1.50-inches height).

8. Inspect all other components removed from the cylinder head.

If a service replacement cylinder head is to be installed, it must be thoroughly cleaned of all rust preventive compound, particularly inside the integral fuel manifolds, before installing the plugs. A simple method of removing the rust-preventive compound is to immerse the head in mineral spirits-based solvent or fuel oil, then scrub the head and go through all the openings with a soft bristle brush. A suitable brush for cleaning the various passages in the head can be made by attaching a 1/8-inch diameter brass rod to brush J 8152. After cleaning, dry the cylinder head with compressed air.

A service replacement cylinder head includes the exhaust valve guides, valve seat inserts, water nozzles, injector tubes, and the necessary plugs.

Assemble Cylinder Head

After cleaning and inspection, assemble the cylinder head as follows:

1. Coat the threads of the plugs with Loctite Pipe Sealant with Teflon, then install the necessary plugs and tighten them to the specified torque (Specifications). Drive headless plugs flush to 0.0625 inch below the surface of the cylinder head.

2. After the following parts are cleaned and inspected, and replaced if necessary, reinstall them in the old cylinder head or transfer them to the new head.

a. Exhaust valves, valve seat inserts, and springs (Exhaust Valve).

b. Cam followers, guides, push rods, springs, retainers, rocker arms, shafts, brackets, and other related parts (Valve Operating Mechanism).

c. Place new washers on the fuel connectors. Then install the connectors and tighten them to 20-28 lb ft (27-38 Nm) torque.

d. The fuel injectors, fuel pipes, and injector control tube assembly can be installed at this time or after the cylinder head is installed on the engine.

Preinstallation Inspection

Make the following inspections just prior to installing the cylinder head, whether the head was removed to service only the head or to facilitate other repairs to the engine.

1. Check the cylinder liner flange heights with relationship to the cylinder block (Cylinder Liner).

2. Make sure the piston crowns are clean and free of foreign material.

3. Make sure that each push rod is threaded into its clevis until the end of the push rod projects through the clevis. This is important since serious engine damage will be prevented when the crankshaft is rotated during engine tune-up.

4. Check the cylinder block and cylinder head gasket surfaces, counterbores, and seal grooves to be sure they are clean and free of foreign material. Also check to ensure that there are no burrs or sharp edges in the counterbores.

5. Inspect the cylinder head boltholes in the block for accumulation of water, oil, or any foreign material.

Clean the boltholes thoroughly and check for damaged threads.

Install Cylinder Head

1. Refer to Fig. 6 and install the water and oil seal rings and compression gaskets as follows:

CAUTION

Never install used compression gaskets or seals.

a. Place a new compression gasket on top of each cylinder liner.

b. Place new seal rings in the counterbores of the water and oil holes in the cylinder block. Silicone composition water hole seals can be damaged if they move out of position in the cylinder block counterbore during engine rebuild. In turn, damaged seals can allow engine coolant to contaminate lube oil and cause serious engine damage. To prevent this, a spray adhesive may be used to hold seals in place if the following precautions are taken: Figure 6. Cylinder Head Gaskets and Seals in Place on Cylinder Block

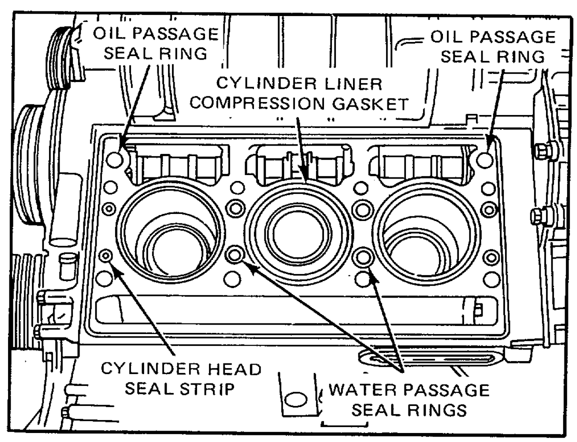


Figure 6. Cylinder Head Gaskets and Seals in Place on Cylinder Block

(1) Attach a mask or template to the cylinder block fire deck to minimize overspray.

(2) Using a high-tack, spray-type adhesive suitable for synthetic rubber seals (3M Company Super-Tack Gasket Adhesive #8082, or equivalent), spray a light, uniform coating of adhesive into the seal counterbores. Keep the adhesive off of adjacent block surfaces and wipe off any that gets on the fire deck or liner bores.

(3) Allow the adhesive to dry to a high-tack consistency (stickiness) before installing the seal. This permits the evaporation of the liquid propellant used with the adhesive.

CAUTION

Do not apply adhesive directly to the seal. The adhesive will coat the I.D. of the seal and the spray propellant may cause the seal to swell temporarily.

c. Install a new oil seal in the groove at the perimeter of the cylinder block. The seal must lay flat in the groove and must not be twisted or stretched.

NOTE

3M Company Super-Tack Gasket adhesive #8082 or equivalent may also be used to hold the peripheral head-to-block oil seals in place during engine rebuild.

NOTE

Installing the seal strip in the groove with the colored stripe facing away from the cylinder bores can improve its sealing capabilities.

2. To install the cylinder head on the engine without disturbing the gaskets and seals, use guide studs J 9665. Install the studs in the end cylinder block boltholes on the camshaft side of the cylinder head (Fig. 2).

3. Attach lifting fixture J 22062-01 to the cylinder head and lift the head into position above the cylinder block (Fig. 2).

4. Make a final visual check of the compression gaskets and seals to ensure that they are in place before the cylinder head is lowered. THIS IS A VERY IMPORTANT CHECK. Gaskets and seals which are not seated properly will cause leaks and blowby, resulting in poor engine performance and damage to the engine.

5. Wipe the bottom of the cylinder head clean. Then lower the head until it is about 1/2-inch from the surface of the cylinder block.

6. Apply a small quantity of International Compound No. 2, or equivalent, to the threads and underside of the head of each cylinder head attaching bolt. Then install the bolts finger tight. On the in-line engines equipped with both six and twelve-point bolts, the twelve-point bolts must be installed on the camshaft side of the head to eliminate possible interference between the governor control link and the cylinder head bolt. Continue to tighten the bolts as the head is lowered on the cylinder block.

CAUTION

Cylinder head bolts are especially designed for this purpose and must not be replaced by ordinary bolts.

7. After the head is in place, remove the guide studs and chain hoist and install the remaining bolts, running all bolts down snug tight with a speed handle (15-20 lb ft or 20-27 Nm torque). However, before tightening the bolts, loosen the lifter bracket-to-cylinder head attaching bolts, otherwise the head may be prevented from seating properly on the cylinder block. A similar condition could exist if the exhaust manifold is attached to the cylinder head. Clearance must be assured between the exhaust manifold and the bosses on the cylinder block. On some engine models, these bosses serve as a rest for the exhaust manifold after the cylinder head has been installed on the cylinder block.

8. Tighten the bolts to 170-180 lb ft (231-244 Nm) torque in 50 lb ft (68 Nm) increments with a torque wrench, as in the sequence shown in Fig. 7. Repeat the tightening sequence at least once, because the first bolts tightened in the sequence tend to lose significant clamp load during tightening of the remaining bolts. Apply a steady pressure for 2 or 3 seconds at the prescribed torque to allow the bolts to turn while the gaskets yield to their final designed thickness. Begin on the cam follower side of the head to take up tension in the push rod springs. Tighten the bolts to the high side of the torque specification, but do not exceed the limit or the bolts may stretch beyond their elastic limits. Attempting to tighten the bolts in one step may result in trouble and consequent loss of time in diagnosis and correction of difficulties, such as compression leaks, when the engine is put into operation.

CAUTION

Tightening the cylinder head bolts will not correct a leaking compression gasket or seal. The head must be removed and the damaged gasket or seal replaced.

9. Cover the oil drain holes in the cylinder head to prevent foreign objects from falling into the holes.

10. If the fuel injectors were not previously installed, refer to Fuel Injector and install them at this time.

11. Tighten the rocker arm bracket bolts to 50-55 lb ft (68-75 Nm) torque.

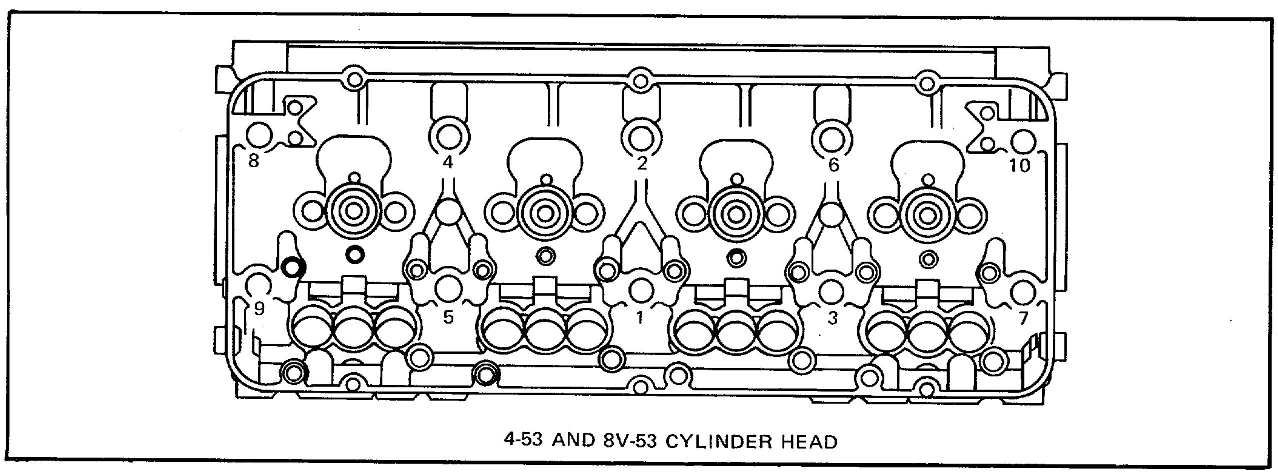


Figure 7 . Cylinder Head Bolt Tightening Sequence

CAUTION

The exhaust valves on a four-valve head may be damaged if the valve bridges are not resting on the ends of the exhaust valves when tightening the rocker arm bracket bolts (refer to Install Rocker Arms and Rocker Arm shaft). Therefore, note the position of the valve bridges before, during, and after tightening the bolts.

12. Align the fuel pipes and connect them to the injectors and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb ft (16-20 Nm) torque.

CAUTION

Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to Pressurize Fuel System Check for Leaks).

13. Set the injector control tube assembly in place on the cylinder head and install the attaching bolts finger tight. When positioning the control tube, be sure the ball end of each injector rack control lever engages the slot in the corresponding injector control rack. With one end of the control tube return spring hooked around an injector rack control lever and the other end hooked around a control tube bracket, tighten the bracket bolts to 10-12 lb ft (14-16 Nm) torque.

14. After tightening the bolts, revolve the injector control tube to be sure the return spring pulls the injector racks out (no-fuel position) after they have been moved all the way in (full fuel position). Since the injector control tube is mounted in self-aligning bearings, tapping the tube lightly will remove any bind that may exist. The injector racks MUST return to the no-fuel position freely by aid of the return spring only. DO NOT BEND THE SPRING. If necessary, replace the spring.

15. Install the fuel rod and the fuel rod cover (if used).

16. Remove the covers from the drain holes in the cylinder head.

17. Install the exhaust manifold and connect the exhaust piping.

18. Install the thermostat housing and thermostat.

19. Install the air cleaner or air silencer.

20. Connect the fuel lines.

21. Install any other equipment that was previously removed.

22. Refer to Preparation for Starting Engine First Time and fill the cooling system and lubrication system.

23. Before starting the engine, perform an engine tune-up as outlined in Engine Tune-up.

VALVE AND INJECTOR OPERATING MECHANISM

Three rocker arms are provided for each cylinder; the two outer arms operate the exhaust valves and the center arm operates the fuel injector.

Each set of three rocker arms pivots on a shaft supported by two brackets. A single bolt secures each bracket to the top of the cylinder head. Removal of the two bracket bolts permits the rocker arm assembly for one cylinder to be raised, providing easy access to the fuel injector and the exhaust valve springs.

The rocker arms are operated by a camshaft through cam followers and short push rods extending through the cylinder head (Fig. 1).

Each cam follower operates in a bore in the cylinder head. A guide for each set of three cam followers is attached to the bottom of the cylinder head to retain the cam followers in place and to align the cam follower rollers with the camshaft lobes. Figure 1. Valve and Injector Operating Mechanism A coil spring, inside of each cam follower, maintains a predetermined load on the cam follower to ensure contact of the cam roller on the camshaft lobe at all times.

Lubrication

The valve and injector operating mechanism is lubricated by oil from a longitudinal oil passage on the camshaft side of the cylinder head, which connects with the main oil gallery in the cylinder block. Oil from this passage flows through drilled passages in the rocker shaft bracket bolts to the passages in the rocker arm shaft to lubricate the rocker arms.

Overflow oil from the rocker arms lubricates the exhaust valves and cam followers. The oil then drains from the top deck of the cylinder head through oil holes in the cam followers, into the camshaft pockets in the cylinder block, and back to the oil pan.

The cam follower rollers are lubricated with oil from the cam followers, oil picked up by the camshaft lobes, and by oil emitted under pressure from grooves in the camshaft bushing bores in the cylinder block.

Service

The following service operations may be performed on the valve and injector operating mechanism without removing the cylinder head:

1. Adjust valve clearance.
2. Replace a valve spring.
3. Replace a rocker arm.
4. Replace a rocker arm shaft or bracket.
5. Replace a fuel injector.

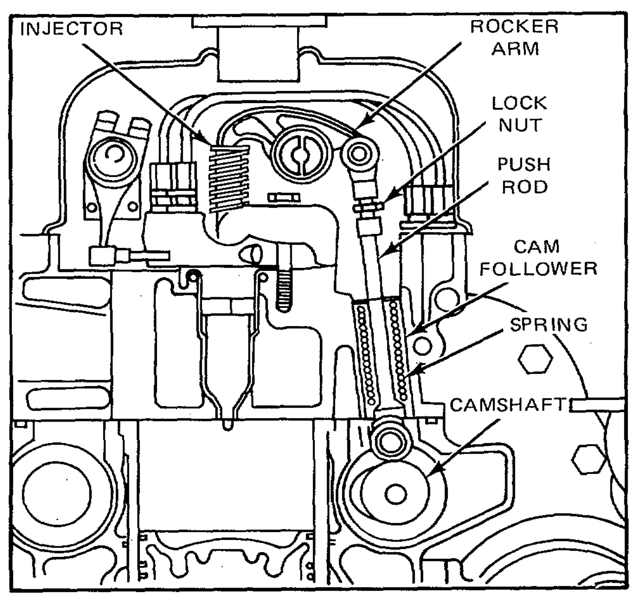


Figure 1. Valve and Injector Operating Mechanism

It is also possible to replace a push rod, push rod spring, the spring seats, or a cam follower without removing the cylinder head. However, these parts are more easily changed from the lower side when the cylinder head is off the engine. Both methods are covered in this section.

To replace the exhaust valves and valve seat inserts, the cylinder head must be removed (refer to Cylinder Head).

Remove Rocker Arms and Shaft

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from the injector and the fuel connectors.

CAUTION

Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

3. Turn the crankshaft, or crank the engine with the starting motor, to bring the injector and valve rocker arms in line horizontally.

CAUTION

Do not bar the crankshaft in a left-hand direction of rotation with a wrench or barring tool on the crankshaft bolt, or the bolt may be loosened.

4. Remove the two bolts which secure the rocker arm shaft brackets to the cylinder head. Remove the brackets and shaft.

CAUTION

When removing the rocker arm shaft, fold the three rocker arms back just far enough so the shaft can be removed. Do not force the rocker arms all the way back with the shaft in place as this may impost a load that could bend the push rods.

5. Loosen the locknuts at the upper ends of the push rods, next to the clevises, and unscrew the rocker arms from the push rods.

CAUTION

If the rocker arms and shafts from two or more cylinders are to be removed, tag them so they may be reinstalled in their original positions.

Inspection

Wash the rocker arms, shaft, brackets, and bolts with clean fuel oil. Use a small wire to clean out the drilled oil passages in the rocker arms and rocker shaft bolts. Dry the parts with compressed air.

Inspect the rocker arm shaft, injector rocker arm bushings, or valve rocker arm bores for wear. A maximum shaft to bushing (or bore) clearance of 0.004 inch is allowable with used parts (refer to Specifications). Service replacement injector rocker arm bushings must be reamed to size after installation.

Inspect the rocker arms for galling or wear on the pallets (valve or injector contact surfaces). If worn, the surface may be refaced up to a maximum of 0.010 inch. However, proceed with caution when surface grinding to avoid overheating the rocker arm. Maintain the radius and finish as close to the original surface as possible. Also, inspect the valve bridges (four-valve head) for wear.

Remove Can Follower and Push Rod (with Cylinder Read on Engine)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

To remove a push rod, spring, spring seats, and cam follower from the top of the cylinder head, proceed as follows:

1. Remove the rocker arm shaft and brackets as outlined under *Remove Rocker Arms and Shaft*.

2. Loosen the locknut and unscrew the rocker arm from the push rod to be removed. Remove the locknut.

3. Install remover J 3092-01, a flat washer and the locknut on the push rod, with the lower end of the tool resting on the upper spring seat.

4. Thread the nut down to compress the spring.

5. Remove the spring seat retainer from the groove in the cylinder head (Fig. 2).

6. Unscrew the locknut to release the spring. Then remove the nut, flat washer, and tool from the push rod.

7. Pull the push rod, spring, spring seats, and cam follower out of the cylinder head.

Remove Can Follower and Push Rod (Cylinder Head Removed)

When removing the cam followers and associated parts, tag them so they may be reinstalled in their original location.

1. Rest the cylinder head on its side (Fig. 3) and remove the cam follower guide.

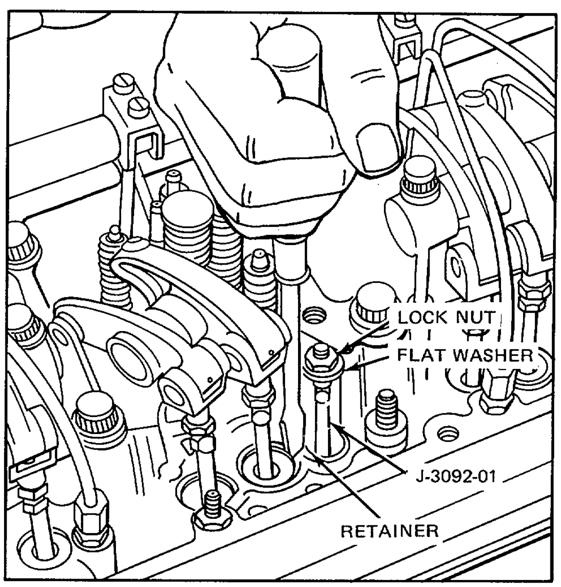


Figure 2. Removing Push Rod from Upper Side of Cylinder Head

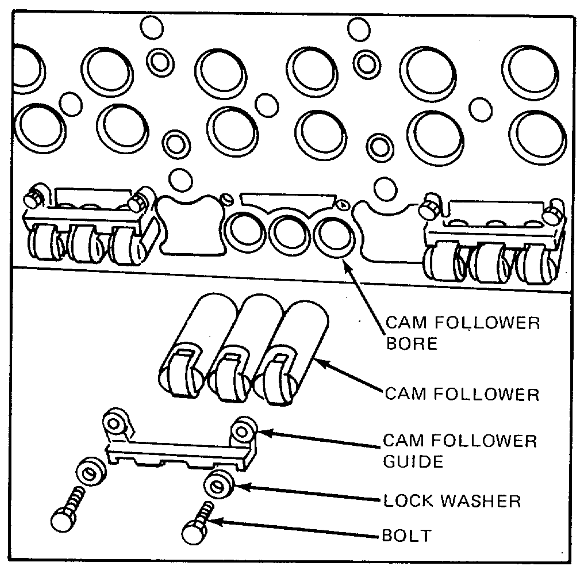


Figure 3. Cam Followers and Guide

2. Pull the cam follower out of the cylinder head.

3. Remove the fuel pipes from the injector and the fuel connectors.

CAUTION

Immediately after removing the fuel pipes, cover the injector fuel inlet and outlet openings with shipping caps to prevent dirt or foreign material from entering.

4. Loosen the push rod locknut and unscrew the push rod from the rocker arm clevis.

5. Pull the push rod and spring assembly from the bottom of the cylinder head.

6. Remove the push rod locknut, spring, and spring seats from the push rod.

NOTE

If the cylinder head is to be replaced, remove the spring retainers and install them in the new head.

Inspection

Proper inspection and service of the cam follower is very necessary to obtain continued efficient engine performance. When any appreciable change in injector timing or exhaust valve clearance occurs during engine operation, remove the cam followers and their related parts and inspect them for excessive wear. This change in injector timing or valve clearance can usually be detected by excessive noise at idle speed.

CAUTION

Wash the cam followers with lubricating oil or Cindol 1705 and wipe dry. DO NOT USE FUEL OIL. Fuel oil working its way in between the cam roller bushing and pin may cause scoring on initial startup of the engine since fuel oil does not provide adequate lubrication.

The push rods, springs, and spring seats may be washed with clean fuel oil and dried with compressed air.

Examine the cam follower rollers for scoring, pitting, or flat spots. The rollers must turn freely on their pins. Measure the total diametric clearance and side clearance. Install a new roller and pin if the clearances exceed those specified in Fig. 4. Cam followers stamped with the letter S on the pin, roller, and follower body are equipped with an oversized pin and roller. The same clearances apply to either a standard or oversized cam follower assembly.

Examine the camshaft lobes for scoring, pitting, or flat spots. Replace the camshaft, if necessary.

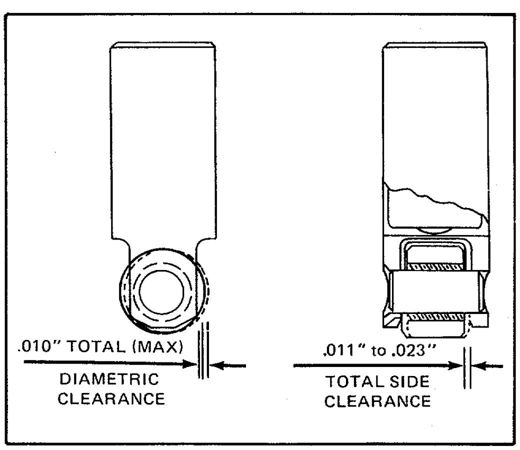


Figure 4. Cam Roller Clearances

Measure the cam follower bores in the cylinder head with a telescope gage and micrometer and record the readings. Measure the diameter of the cam followers with a micrometer. Record the readings and compare the readings of the followers and bores to determine the cam follower-to-bore clearances (refer to *Specifications*).

Inspect the push rods and spring seats for wear.

Examine the cam follower springs for wear or damage and check the spring load.

The current push rod spring (Fig. 6) is made from 0.1920-inch diameter wire and was first used only in the injector cam follower position, effective with engine 4D-5323.

Effective with engine 4D-8549, the new spring is also used in the exhaust valve cam follower position. The former push rod spring was made from 0.1770-inch diameter wire.

Use spring tester J 22738-02 to check the spring load (Fig. 5). Replace the current-type spring when a load of less than 250 pounds (1112 N) will compress it to a length of 2.1406 inches. Replace the former-type spring when a load of less than 172 pounds (765 N) will compress it to a length of 2.1250 inches.

It is recommended that if one former type push rod spring requires replacement, all of the former-type springs in either the injector or valve cam follower positions be replaced by the current-type spring. A new design upper spring seat is required with the use of the current push rod spring.

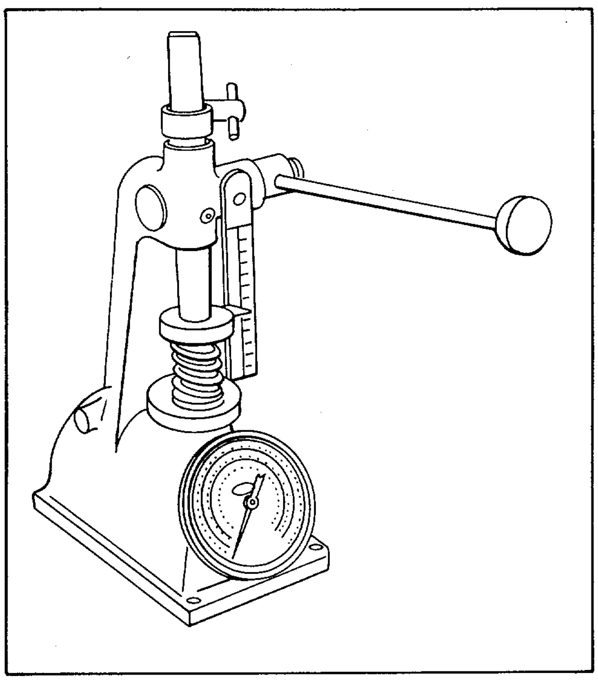


Figure 5. Testing Cam Follower Spring

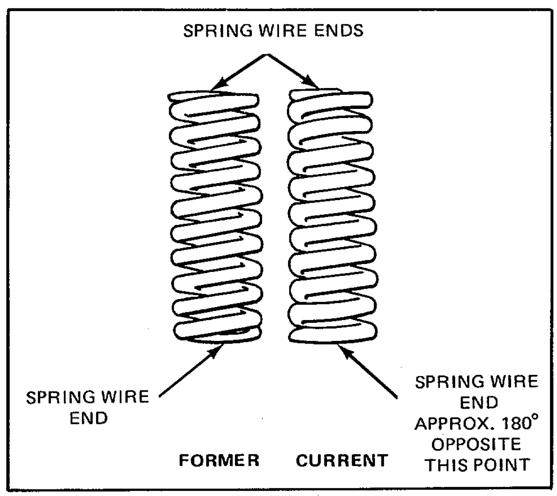


Figure 6. Spring Identification

Replace Cam Roller and Pin

To replace a cam roller and pin, proceed as follows:

CAUTION

Do not attempt to bore out the legs of a standard cam follower for an oversized pin.

1. Clamp fixture J 5840-01 securely in a vise as shown in Fig. 7. Then place the cam follower in the groove in the top of the fixture, with the follower pin resting on top of the corresponding size plunger in the fixture.

2. Drive the pin from the roller with a suitable drift. Exercise caution in removing the cam follower body and roller from the fixture as the roller pin is seated on a spring-loaded plunger in the fixture.

3. Before installing the new roller and pin, remove the preservative by washing the parts with clean lubricating oil or Cindol 1705 and wipe dry. DO NOT USE FUEL OIL. After washing the parts, lubricate the roller and pin with Cindol 1705.

4. Position the cam follower body in the groove of the fixture, with the small plunger extending through the roller pinhole in the lower leg of the follower body.

5. Position the new cam roller in the cam follower body. When released, the plunger will extend into the roller bushing and align the roller with the cam follower body.

6. Start the new pin in the cam follower body, then carefully tap it in until it is centered in the cam follower body.

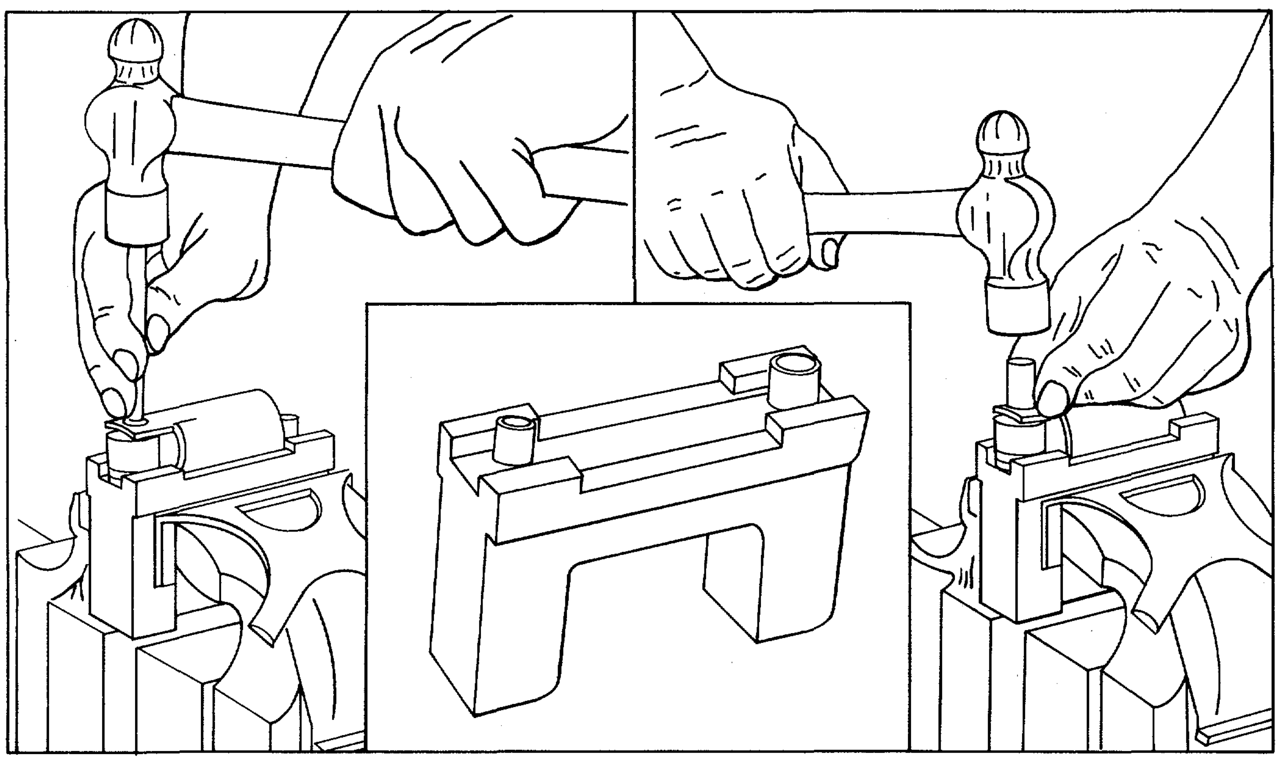


Figure 7. Removing or Installing Cam Follower Roller and Pin Using Tool J 5840-01

7. Remove the cam follower from the fixture and check the side clearance (Fig. 4). The clearance must be 0.011 to 0.023 inch.

Install Cam Follower and Push Rod

If new cam follower assemblies are to be installed, remove the preservative by washing with Cindol 1705 and wipe dry. DO NOT USE FUEL OIL.

Before cam followers are installed, immerse them in clean Cindol 1705 (heated to 100-125°F or 38-52°C) for at least one hour to ensure initial lubrication of the cam roller pins and bushings. Rotate the cam rollers during the soaking period to purge any air from the bushing-roller area. The heated Cindol oil results in better penetration as it is less viscous than engine oil and flows more easily between the cam roller bushing and pin. After the cam followers are removed from the heated Cindol 1705, the cooling action of any air trapped in the bushing and pin area will tend to pull the lubricant into the cavity.

CAUTION

Heat the Cindol 1705 in a small pail with a screen insert. The screen will prevent the cam followers from touching the bottom of the pail and avoid the possibility of contamination.

Install used cam followers and push rods in their original locations. Refer to Fig. 8 and proceed as follows:

CYLINDER HEAD ON ENGINE

1. Note the oilhole in the bottom of the cam follower. With the oilhole directed away from the exhaust valves, slide the cam follower in position in the cylinder head.
2. Assemble the serrated lower spring seat, spring, and upper cupshaped spring seat on the push rod.

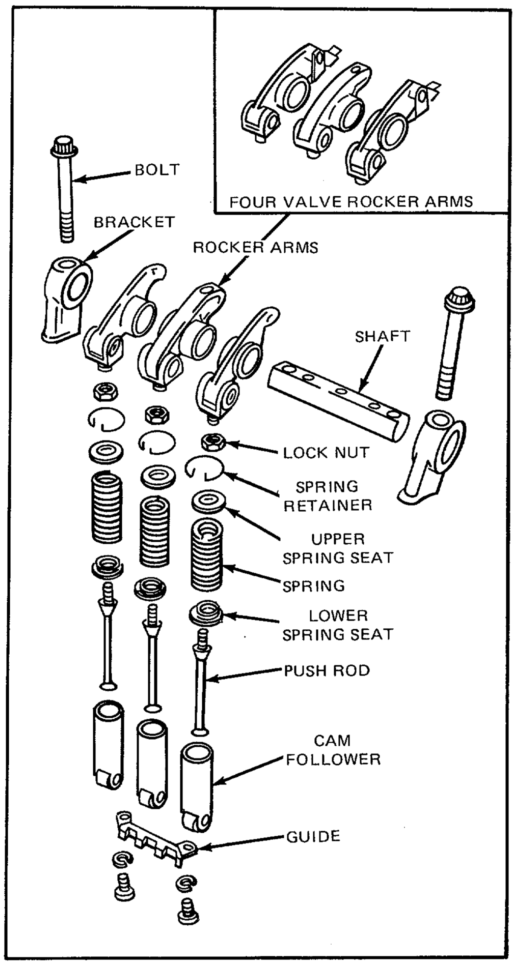


Figure 8. Valve and Injector Operating Mechanism and Relative Location of Parts

NOTE

The current cup-shaped upper spring seat can be used with either the former or current spring.

3. Place a flat washer over the upper spring seat and start the locknut on the push rod. Place tool J 3092-01 on the push rod between the washer and

the upper spring seat and place the push rod assembly in the cam follower. Then thread the locknut on the push rod until the spring is compressed sufficiently to permit the spring retainer to be installed. Then install the spring retainer.

4. Remove the nut, flat washer, and tool. Then reinstall the locknut and thread it as far as possible on the push rod.

CYLINDER HEAD REMOVED FROM ENGINE

Refer to Fig. 8 and install the cam follower and push rod as follows:

1. Assemble the serrated lower spring seat, spring, upper cup-shaped spring seat, and locknut on the push rod.

NOTE

The current cup-shaped upper spring seat can be used with either the former or current spring.

2. With the spring retainer in place in the cylinder head, slide the push rod assembly in position from the bottom of the head.

3. Note the oilhole in the bottom of the cam follower. With the oilhole directed away from the exhaust valves, slide the cam follower in position from the bottom of the head.

4. Attach the follower guide to the cylinder head to hold the group of three cam followers in place. Tighten the guide bolts to 12-15 lb ft (16-20 Nm) torque. Check to be sure there is at least 0.005-inch clearance between the cam follower legs and the cam follower guide (Fig. 9). If there is insufficient clearance, loosen the guide bolts slightly and tap each corner of the guide with a brass rod (Fig. 10). Then retighten the bolts to the specified torque.

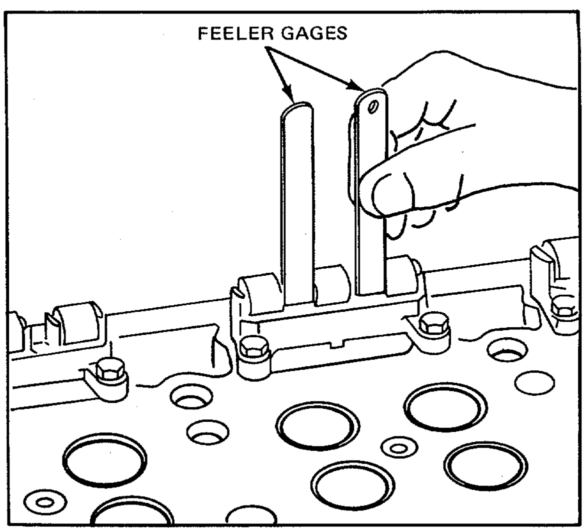


Figure 9. Checking Cam Follower to Guide Clearance

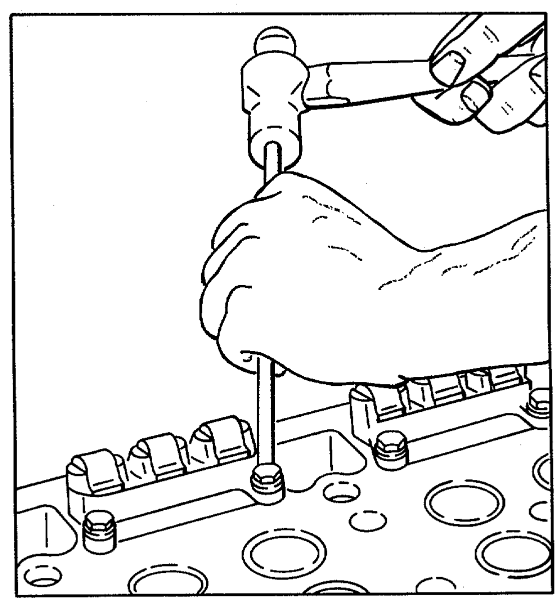


Figure 10. Adjusting Cam Follower Guide

CAUTION

> It is important to use the correct bolts as prescribed in the parts books. The hardened bolt is necessary to obtain the proper torque and to withstand the stress imposed on it during engine operation.

Install Rocker Arms and Shaft

Note that the injector rocker arm (center arm of the group) is slightly different from the exhaust valve rocker arms; the boss for the shaft on the left and right-hand valve rocker arms is longer on one side. The extended boss of each valve rocker arm must face toward the injector rocker arm.

1. Thread each rocker arm on its push rod until the end of the push rod is flush with or above the inner side of the clevis yoke. This will provide sufficient initial clearance between the exhaust valve and the piston when the crankshaft is turned during the valve clearance adjustment procedure.

2. If removed, install the cylinder head on the engine (refer to Cylinder Head).

3. If removed, install the fuel injectors.

4. Apply clean engine oil to the rocker arm shaft and slide the shaft through the rocker arms. Then place a bracket over each end of the shaft, with the finished face of the bracket next to the rocker arm.

5. Insert the rocker arm bracket bolts through the brackets and the shaft. Tighten the bolts to the specified torque (refer to *Specifications*). Check to make sure there is some clearance between the rocker arms.

CAUTION

> On four-valve cylinder heads, there is a possibility of damaging the exhaust valves if the valve bridge is not resting on the ends of the valves when tightening the rocker arm shaft bracket bolts (Fig. 11). Therefore, note the position of the valve bridges before, during, and after tightening the bolts.

6. Align the fuel pipes and connect them to the injectors and the fuel connectors. Tighten the fuel pipe nuts to 12-15 lb ft (16-20 Nm) torque using socket J 8932-01.

CAUTION

> Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared ends of the fuel pipes and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings.

7. Fill the cooling system.

8. Adjust the exhaust valve clearance (*Exhaust Valve Clearance*) and time the injectors (*Fuel Injector Timing*).

9. If necessary, perform an engine tuneup.

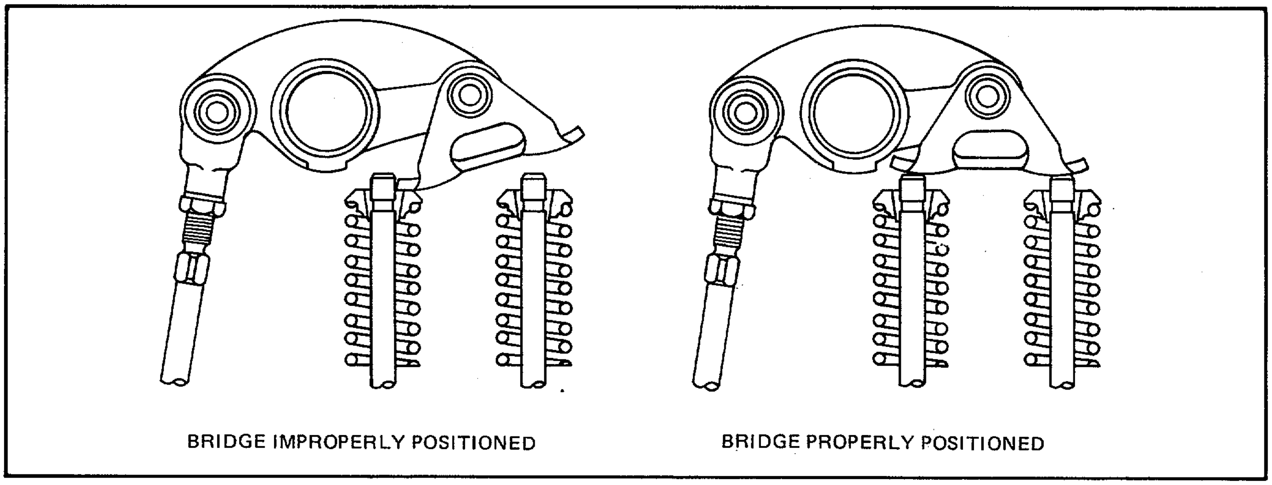


Figure 11. Relationship Between Exhaust Valve Bridge and Valve Stems

EXHAUST VALVES

Two or four exhaust valves are provided for each cylinder (Fig. 1), depending upon the engine model. The valve heads are heat treated and ground to the proper seat angle and diameter. The valve stems are ground to size and hardened at the end which contacts the rocker arm (two-valve head) or the exhaust valve bridge (four-valve head).

The exhaust valve stems are contained within exhaust valve guides which are pressed into the cylinder head. Exhaust valve seat inserts, pressed into the cylinder head, permit accurate seating of the exhaust valves under varying conditions of temperature and materially prolong the life of the cylinder head. The exhaust valves are ground to a 30° seating angle while the exhaust valve seat inserts are ground to a 31° seating angle.

The exhaust valve springs are held in place by the valve spring caps and tapered two-piece valve locks.

Excess oil from the rocker arms lubricates the exhaust valve stems. The valves are cooled by the flow of air from the blower past the valves each time the air inlet ports are uncovered.

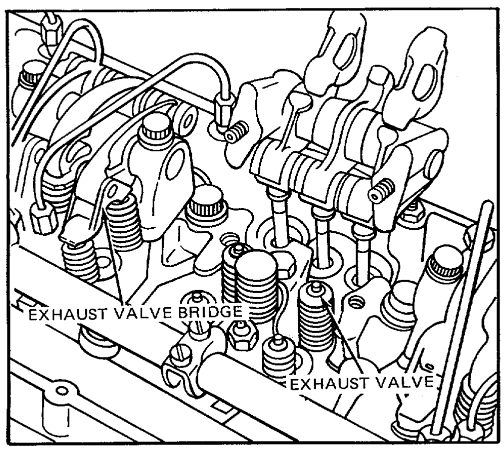


Figure 1. Location of Exhaust Valves

Exhaust Valve Maintenance

Efficient combustion in the engine requires that the exhaust valves be maintained in good operating condition. Valve seats must be true and unpitted to assure leak-proof seating, valve stems must work freely and smoothly within the valve guides, and the correct valve clearance (*Exhaust Valve Clearance Adjustment*) must be maintained.

Proper maintenance and operation of the engine is important to long valve life. Engine operating temperatures should be maintained between 160-185°F (71-85°C). Low operating temperatures (usually due to extended periods of idling or light engine loads) result in incomplete combustion, formation of excessive carbon deposits and fuel lacquers on valves and related parts, and a greater tendency for lubricating oil to sludge.

Unsuitable fuels may also cause formation of deposits on the valves, especially when operating at low temperatures.

When carbon deposits, due to partially burned fuel, build up around the valve stems and extend to that portion of the stem which operates in the valve guide, sticking valves will result. Thus, the valves cannot seat properly, and pitted and burned valves and valve seats and loss of compression will result.

Lubricating oil and oil filters should be changed periodically to avoid accumulation of sludge.

Valve sticking may also result from valve stems which have been scored due to foreign matter in the lubricating oil, leakage of antifreeze (glycol) into the lubricating oil which forms a soft sticky carbon and gums the valve stems, and bent or worn valve guides.

Sticking valves may eventually become bent or broken by being held in the open position and struck by the piston.

It is highly important that injector timing and valve clearance be accurately adjusted and checked periodically. Improperly timed injectors or tightly adjusted valves will have adverse effects upon combustion.

Remove Exhaust Valve Spring (Cylinder Head Installed)

An exhaust valve spring may be removed, without removing the cylinder head from the engine, as follows:

1. Clean and remove the valve rocker cover.

2. Crank the engine over to bring the valve and injector rocker arms in line horizontally.

CAUTION

When using a wrench on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation as this could loosen the bolt.

3. Disconnect and remove the fuel pipes from the injector and the fuel connectors.

CAUTION

Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

4. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and shaft.
5. Remove the cylinder block air box cover so that piston travel may be observed, then turn the crankshaft until the piston is at the top of its stroke.
6. Thread the valve spring compressor adapter tool J 7455-4 into one of the rocker arm bracket boltholes in the cylinder head (Fig. 2). Then compress the spring and remove the two-piece valve lock.
7. Release the tool and remove the valve spring cap, valve spring, and spring seat.

Remove Exhaust Valves and Valve Springs (Cylinder Read Removed)

With the cylinder head removed from the engine, remove the exhaust valves and springs as follows:

1. Support the cylinder head on 2-inch thick woodblocks to keep the cam followers clear of the bench.
2. Remove the fuel pipes from the injectors and the fuel connectors.

CAUTION

Immediately after removing the fuel pipes, cover each injector opening with a shipping cap to prevent dirt or other foreign matter from entering the injector.

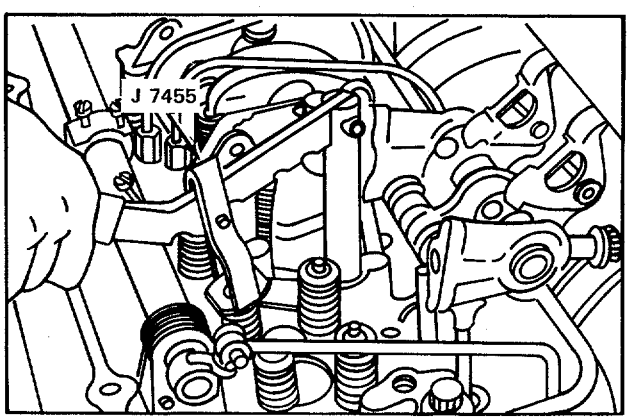


Figure 2. Removing Valve Spring Using Tool J 7455

3. Remove the two bolts holding the rocker arm shaft brackets to the cylinder head. Then remove the brackets and the shaft.

4. Remove the fuel injectors.

5. Place a block of wood under the cylinder head to support the exhaust valves. Remove the exhaust valve springs as outlined in steps 6 and 7 above.

6. Turn the cylinder head over, using care to keep the valves from falling out of the head. If the valves are to be reused, number each valve to facilitate reinstallation in the same location. Then withdraw the valves from the cylinder head.

7. Remove the cam followers and push rod assemblies as outlined in *Valve Operating Mechanism* under *Remove Cam Follower* and *Push Rod Assembly (Cylinder Head Removed from Engine).*

Inspection

Clean the springs with fuel oil, dry them with compressed air, and inspect them. Replace a pitted or fractured spring.

Use spring tester J 22738-02 to check the spring load (Fig. 3). Replace a spring if a load of less than 33 pounds will compress a two-valve cylinder head spring to 2.31 inches, or a load of less than 25 pounds will compress a four-valve cylinder head spring to 1.93 inches. The difference in the load between a pair of four-valve cylinder head springs must not exceed 6 pounds or the valve bridge will be unbalanced.

To eliminate exhaust valve spring surge, a new valve spring (0.148-inch wire diameter) is used in the in-line 4-53 engine. The change is effective with approximate engine serial numbers 4D-112278 and 6D-82217. The former spring was made from 0.135-inch diameter wire.

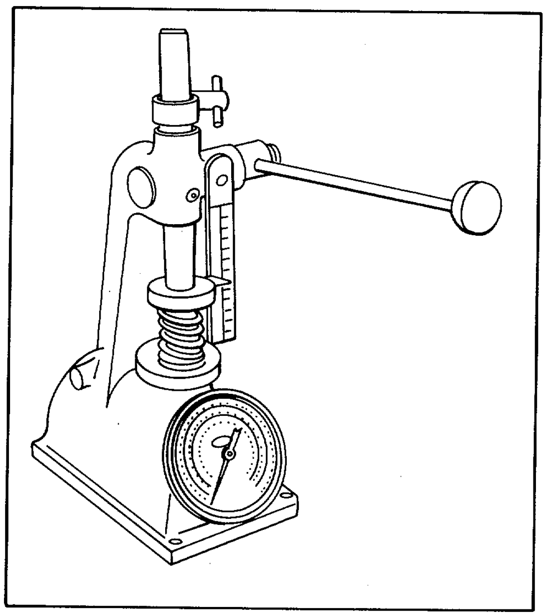


Figure 3. Testing Valve Spring Using Tool J 22738-02

The new spring can be used only in engines built after serial numbers 4D-112278 and 6D-60776 and use the present low-lift camshaft, or older engines which have these low-lift camshafts installed.

CAUTION

The use of the new spring with the former high-lift camshaft (O.327-inch valve cam lobe lift, metal stamped V7 or V at both ends) will cause the valve springs to bottom out, resulting in bent push rods and possible engine damage.

NOTE

The low-lift camshaft which provides a maximum valve cam lobe lift of 0.276-inch is metal stamped V7L at both ends.

For service replacement, change the new spring when a load of less than 25 pounds will compress it to 1.93 inches (installed length).

The new and former valve springs are interchangeable in an engine rated below 2800 rpm using a low-lift (V7L) camshaft. However, on any given valve bridge, it is recommended that both springs be the same.

When a former spring is replaced in an engine rated at 2800 rpm with a low-lift (V7L) camshaft, all of the springs must be replaced with the new spring.

Inspect the valve spring seats and caps for wear. If worn, replace with new parts.

Carbon on the face of a valve could indicate blowby due to a faulty seat. Black carbon deposits extending from the valve seats to the valve guides may result from cold operation due to light loads or the use of too heavy a grade of fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the valve guides is evidence of high operating temperatures. High operating temperatures are normally due to overloads, inadequate cooling, or improper timing which results in carbonization of the lubricating oil.

If there is evidence of engine oil running down the exhaust valve stem into the exhaust chamber, creating a high oil consumption condition because of excessive idling and resultant low engine exhaust back pressure, replace the valve guide oil seals or, if not previously used, install valve guide oil seals.

Effective with four-valve cylinder head engines built the second quarter of 1980, a new exhaust valve guide oil seal is being used. The new oil seal (Fig. 17) has a metal case and the slightly reduced inner diameter of the seal provides a press fit on the valve guide. The former oil seal was retained by a spring at the small end and a retainer at the large end. The former and current oil seals are interchangeable on a cylinder head.

Clean the carbon from the valve stems and wash the valves with fuel oil. The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges, cracks, or pitting. If necessary, reface the valves or install new valves. If the valve heads are warped, replace the valves.

Clean the inside diameter of the valve guides with brush J 7793 as shown in Fig. 4. This brush will remove all gum or carbon deposits from the valve guides, including the spiral grooves.

Inspect the valve guides for fractures, chipping, scoring, or excessive wear. Measure the valve guide inside diameter with a pin gage or inside micrometer and record the readings. After inspecting and cleaning the exhaust valves, measure the outside diameter of the valve stems with a micrometer and record the readings. Compare the readings to obtain the valve-to-guide

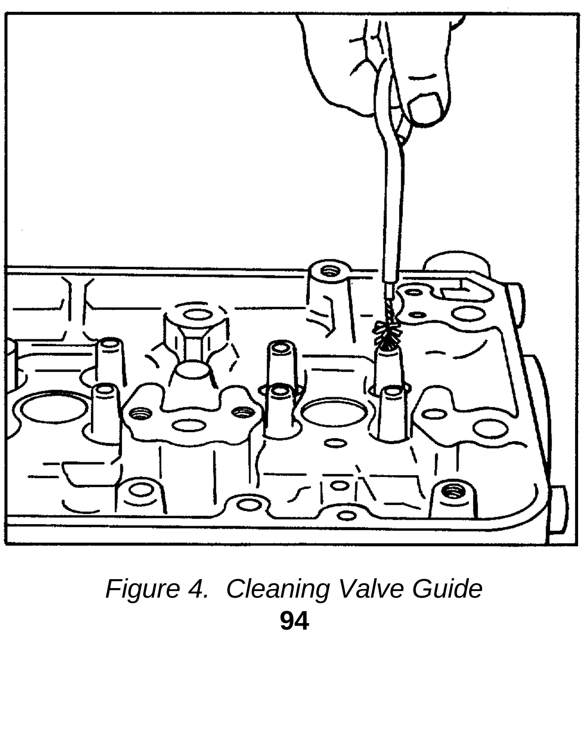


Figure 4. Cleaning Valve Guide

clearance. If the clearance exceeds 0.006 inch (two-valve head) or 0.005 inch (four-valve head), replace the valve guides.

Replace Exhaust Valve Guide

Remove the exhaust valve guide as follows:

1. Remove and discard the coil seal, if used.

2. Support the cylinder head, bottom side up, on 3-inch thick woodblocks.

3. Drive the valve guide out of the cylinder head with valve guide remover J 7775 as shown in Fig. 5.

The current valve guides have a 45° chamfer at the top, replacing the former guides with a 15° chamfer. In addition, the guide for the four-valve cylinder head is machined for use of an oil seal (Fig. 6).

Install the exhaust valve guide as follows:

1. Place the cylinder head right side up on the bed of the arbor press.

2. Insert the internally threaded end of the valve guide in the proper valve guide installing tool (refer to the *Valve Guide Installing Tools* chart (Fig. 7)).

NOTE

When replacing the exhaust valve guides in a cylinder head, the current guide, which is machined for use with an oil seal, should be used in place of the 45° chamfered guide (Fig. 6). The current guide will facilitate field installation of valve guide oil seals.

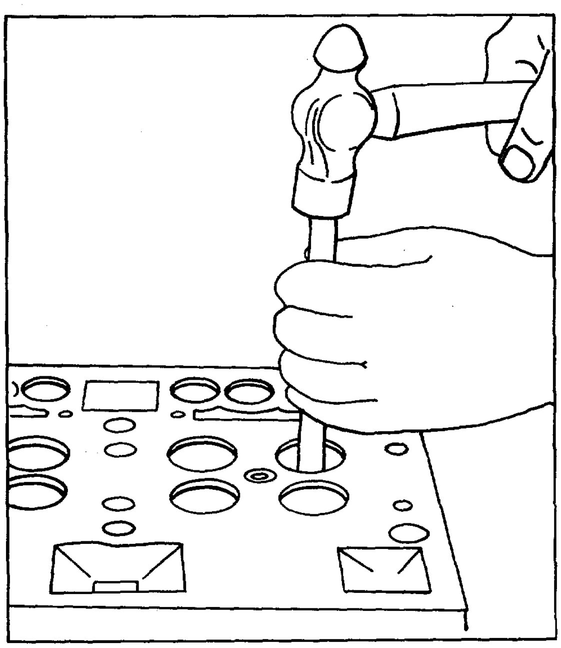


Figure 5. Removing Valve Guide

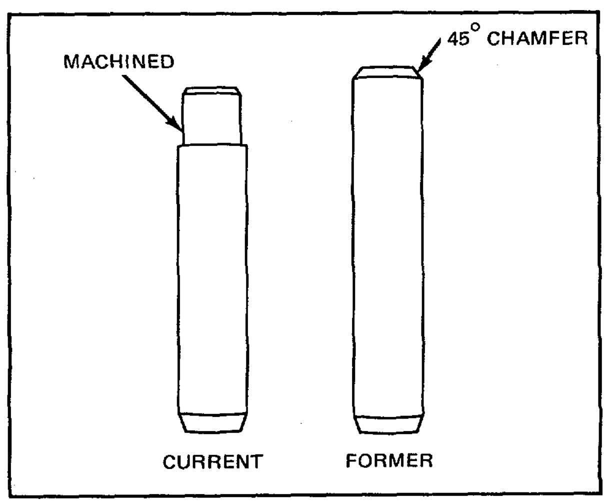
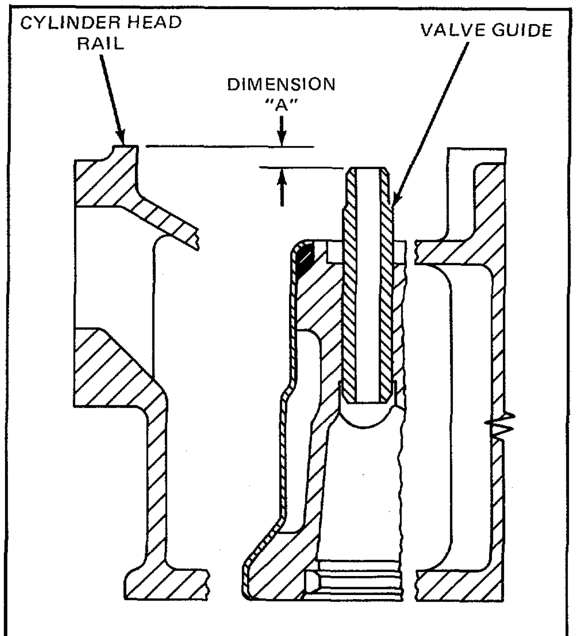


Figure 6. Former and Current Valve Guides



TOOL NO.	CYL. HEAD	VALVE GUIDE	DIMENSION "A"
J 7560	2 VALVE	15° CHAMFER	.010"-.040"
J 7832	4 VALVE	15° CHAMFER	.010"-.040"
J 9756	2 VALVE	45° CHAMFER	.010"-.040"
J 9730	4 VALVE		.190"-.220"

• MACHINED FOR USE WITH VALVE GUIDE OIL SEAL.

Figure 7. Valve Guide Installing Tools

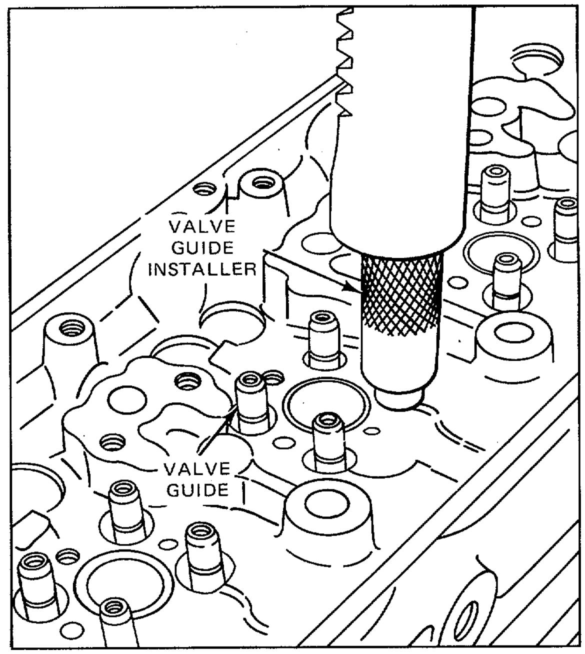


Figure 8. Installing Valve Guide

CAUTION

Be sure to use the correct tool to avoid damage to the valve guide and to locate the valve guide to the proper dimension.

3. Position the valve guide squarely in the bore in the cylinder head and press the installing tool gently to start the guide in place (Fig. 8). Then press the guide in until the tool contacts the cylinder head (the bottom of the counterbore in the four-valve cylinder head).

CAUTION

Do not use the valve guides as a means of turning the cylinder head over or in handling the cylinder head.

Inspect Exhaust Valve Seat Insert

Inspect the exhaust valve seat inserts for excessive wear, pitting, or cracking.

Remove Exhaust Valve Seat Insert

The valve seat inserts are pressed into the cylinder head and must be removed as outlined in the following procedure to avoid damage to the cylinder head:

1. Place the cylinder head on its side on a bench as shown in Fig. 9.

2. Place the collet of tool J 7774 inside-the valve insert so that the bottom of the collet is flush with the bottom of the insert.

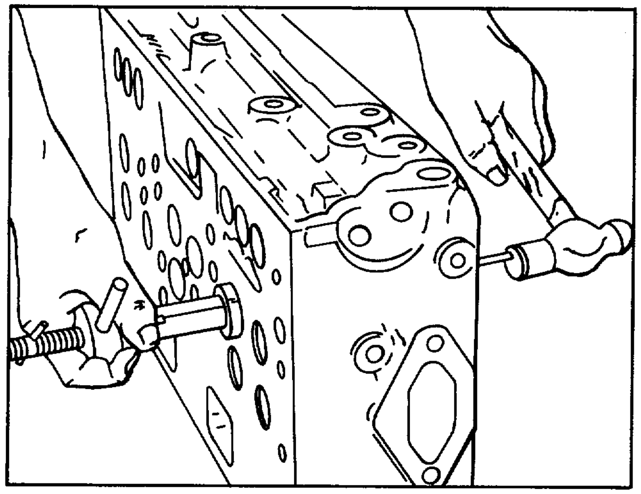


Figure 9. Removing Valve Seat Insert

3. Hold the collet handle and turn the T-handle to expand the collet cone until the insert is held securely by the tool.
4. Insert the drive bar of the tool through the valve guide.
5. Tap the drive bar once or twice to move the insert about 1/16 inch away from its seat in the cylinder head.
6. Turn the T-handle to loosen the collet cone and move the tool into the insert slightly so the narrow flange at the bottom of the collet is below the valve seat insert.
7. Tighten the collet cone and continue to drive the insert out of the cylinder head.

NOTE

In addition to the above procedure, remover J 23479-15 and appropriate collet can be used to remove the exhaust valve insert from the cylinder head.

Install Exhaust Valve Seat Insert

1. Clean the valve seat insert counterbores in the head with trichloroethylene or other suitable solvent. Also wash the valve seat inserts with the same solvent. Dry the counterbores and the inserts with compressed air.
2. Inspect the counterbores for cleanliness, concentricity, flatness, and cracks. The counterbores for the valve seat inserts in a two-valve head have a diameter of 1.439 to 1.440 inches and a depth of 0.294 to 0.306 inch. The counterbores for the valve seat inserts in a four-valve head have a diameter of 1.159 to 1.160 inches and a depth of 0.294 to 0.306 inch on former engines and a depth of 0.300 to 0.312 inch on current engines.

NOTE

Valve seat inserts which are 0.010 inch oversize on the outside diameter are available, if required.

3. Immerse the cylinder head for at least 30 minutes in water heated to 180-200°F (82-93°C).

4. Rest the cylinder head, bottom side up, on a bench and place an insert in the counterbore--valve seat side up. This must be done quickly while the cylinder head is still hot and the insert is cold (room temperature). If the temperature of the two parts is allowed to become nearly the same, installation may become difficult and damage to the parts may result.

5. Drive the insert in place with installer J 6976 (two-valve head) or J 7790 (four-valve head) as shown in Fig. 10 until it seats solidly in the cylinder head.

6. Grind the valve seat insert and check it for concentricity in relation to the valve guide as outlined below.

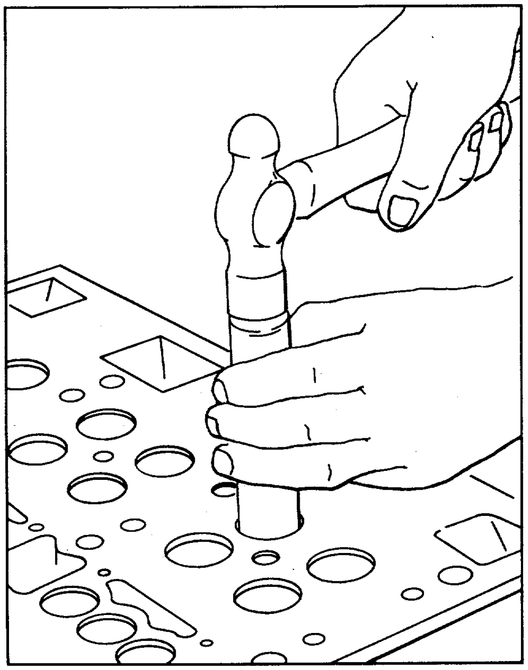


Figure 10. Installing Valve Seat Insert

Recondition Exhaust Valve and Valve Seat Insert

An exhaust valve which is to be reused may be refaced, if necessary (Fig. 11). To provide sufficient valve strength and spring tension, the edge of the valve at the valve head must not be less than 1/32 inch in thickness and must still be within the specifications shown in Fig. 13 after refacing.
Before either a new or used valve is installed, examine the valve seat in the cylinder head for proper valve seating. The proper angle for the seating face of the valve is 30° and for the valve seat insert it is 31°.
When a new valve seat insert is installed or an old insert refaced, the work must be done with a grinding wheel (Fig. 12).

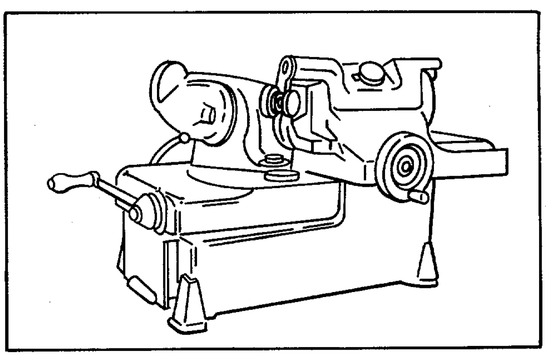


Figure 11. Refacing Exhaust Valve

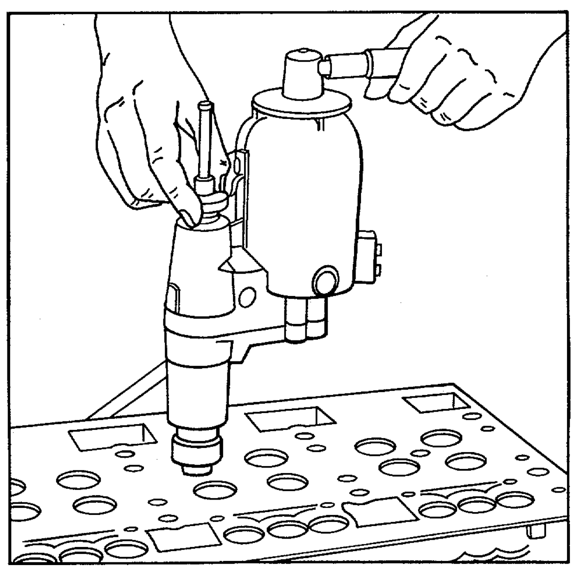


Figure 12. Grinding Valve Seat Insert

The eccentric grinding method for reconditioning valve seat inserts is recommended. This method produces a finer, more accurate finish since only one point of the grinding wheel is in contact with the valve seat at any time. A micrometer feed permits feeding the grinding wheel into the work 0.001 inch at a time.

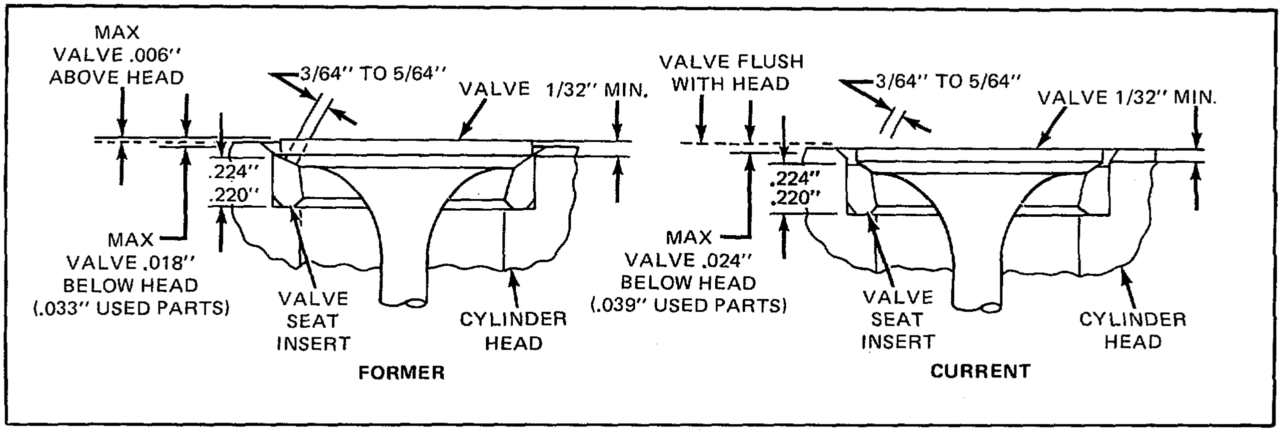


Figure 13. Relationship Between Exhaust Valve, Insert, and Cylinder Head (Four-Valve Head)

To grind the valve seat inserts for a four-valve cylinder head, use the following tools:

1. Grinder J 8165-1
2. Dial Gage J 8165-2
3. Pilot J 7792-1
4. Grinding Wheel (150) J 7792-2
5. Grinding Wheel (31°) J 7792-3
6. Grinding Wheel (60°) J 7792-4

Grind the valve seat inserts as follows:

1. First apply the 31° grinding wheel on the valve seat insert.
2. Using the 60° grinding wheel to open the throat of the insert.
3. Then grind the top surface with a 15° wheel to narrow the width of the seat from 3/64 to 5/64 inch (Fig. 13). The 31° face of the insert may be adjusted relative to the center of the valve face with 15° and 60° grinding wheels.

CAUTION

Do not permit the grinding wheel to contact the cylinder head when grinding the insert. If necessary, replace the insert.

The maximum amount that the exhaust valve should protrude beyond the cylinder head (when the valve is in the closed position), and still maintain the proper piston-to-valve clearance, is shown in Fig. 13. Grinding will reduce the thickness of the valve seat insert and cause the valve to recede into the cylinder head. If, after several grinding operations, the valve recedes beyond the specified limits, replace the valve seat insert.

When occasion requires, the grinding wheel may be dressed to maintain the desired seat angle with the dressing tool provided with the grinder set (Fig. 14).

After grinding has been completed, clean the valve seat insert thoroughly with fuel oil and dry it with compressed air. Set the dial indicator J 8165-2 in position as shown in Fig. 15 and rotate it to determine the concentricity of each valve seat insert

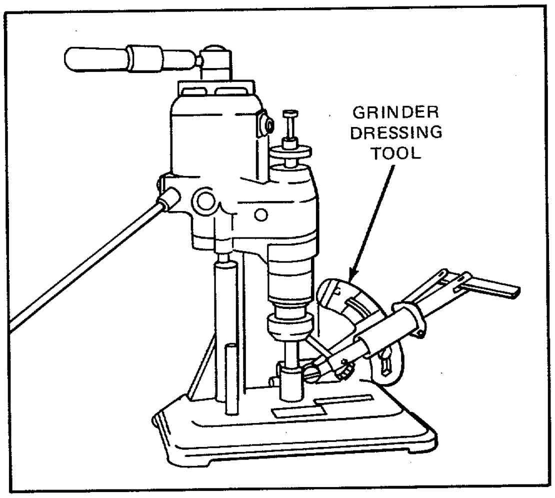


Figure 14. Grinding Wheel Dressing Tool of Set J 8165-1

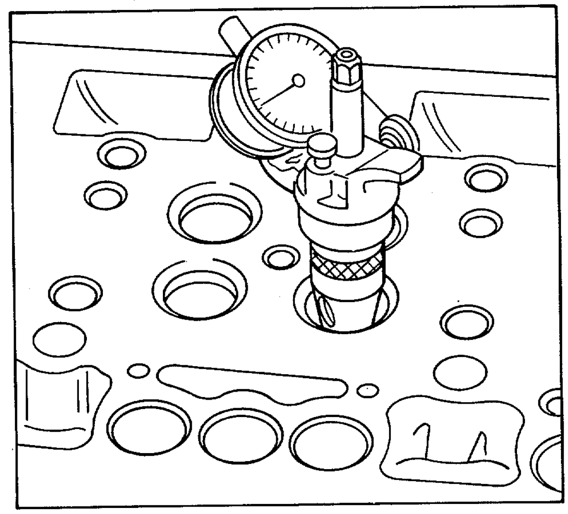


Figure 15. Checking Relative Concentricity at Valve Seat Insert with Relation to Valve Guide

relative to the valve guide. If the runout exceeds 0.002 inch, check for a bent valve guide before regrinding the insert.

4. After the valve seat insert has been ground, determine the position of the contact area between the valve and the valve seat insert as follows:

a. Apply a light coat of Prussian Blue or similar paste to the valve seat insert.

b. Lower the stem of the valve in the valve guide and bounce the valve on the seat. DO NOT ROTATE THE VALVE. This procedure will show the area of contact (on the valve face). The most desirable area of contact is at the center of the valve face.

CAUTION

The user of valve lapping compound is not recommended.

After the valve seat inserts have been ground and checked, thoroughly clean the cylinder head before installing the valves.

Install Exhaust Valves and Springs

When installing exhaust valves, check to see that the valves are within the specifications shown in Fig. 13. Also, do not use N-pistons with former four-valve cylinder head assemblies unless the valves are flush with the cylinder head. If the valves are not flush, it may be necessary to regrind the valve seats so that the valves will be flush with the bottom surface of the cylinder head.

NOTE

The distance from the top of the four-valve cylinder head to the bottom of the valve spring seat counterbore is 1 11/64 inches in current design cylinder heads or 1 5/64 inches in former design heads.

Be sure and install the correct parts in the four-valve cylinder head. Current design cylinder heads are equipped with the thin valve spring seats (0.060 inch) and current design exhaust valves

(Fig. 16). To facilitate replacement of a four-valve head on an engine using the former exhaust valves, the proper quantity of the thick spring seats (0.150 inch) must be used.
Service cylinder heads are of the current design. The current thin valve springs seats (0.060 inch) are included with each cylinder head as a shipped loose item.

1. Lubricate the valve stems with sulphurized oil (E.P. type) and slide the valves all the way into the guides.

CAUTION

If reconditioned valves are used, install them in the same relative location from which they were removed.

2. Hold the valves in place temporarily with a strip of masking tape. Then, turn the cylinder head right side up on the workbench. Place a board under the head to support the valves and to provide clearance between the cam followers and the bench.

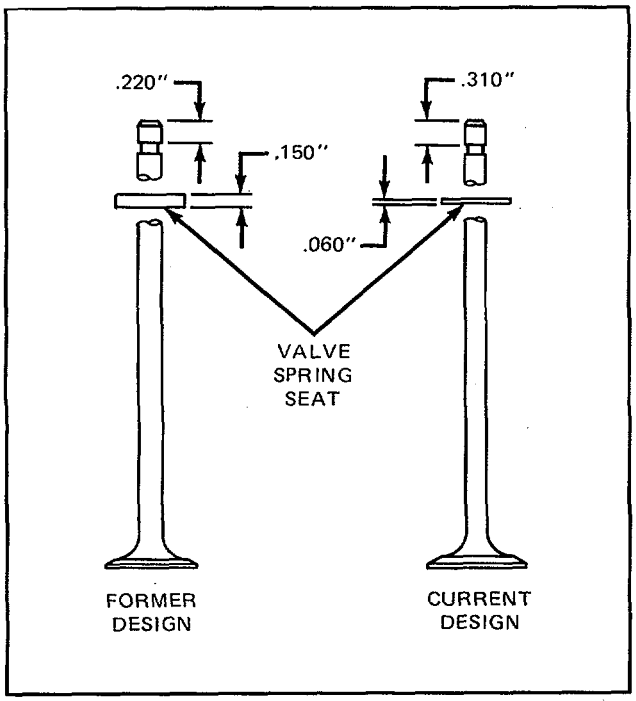


Figure 16. Former and Current Design Exhaust Valves (Four-Valve Head)

3. Install the valve spring seats.
4. Install the valve guide oil seals, if used, on the valve guides as follows:
   a. Former Oil Seal (retained by a spring and retainer)
      (1) Place the plastic seal installation cap on the end of the valve stem. If the cap extends more than 1/16 inch below the groove on the valve stem, remove the cap and cut off the excess length.
      (2) Lubricate the installation cap and start the seal carefully over the valve stem. Push the seal down slowly until it rests on top of the valve guide.
      (3) Remove the installation cap.
   b. Current Oil Seal (Fig. 17) (metal case and reduced inner diameter)

NOTE

To properly install the current oil seal, use oil seal installer J 29579.

(1) Lubricate the oil seal and the valve stem with engine oil and start the oil seal carefully over the valve stem.

(2) Using installer J 29579, drive the seal down slowly until the tool bottoms on the cylinder head (spring seat washer removed).

CAUTION

The tool positions the seal so that it does not bottom out on the valve guide. If the oil seal is installed too far, so as to contact the top of the guide, it will be distorted and will not function as an effective seal.

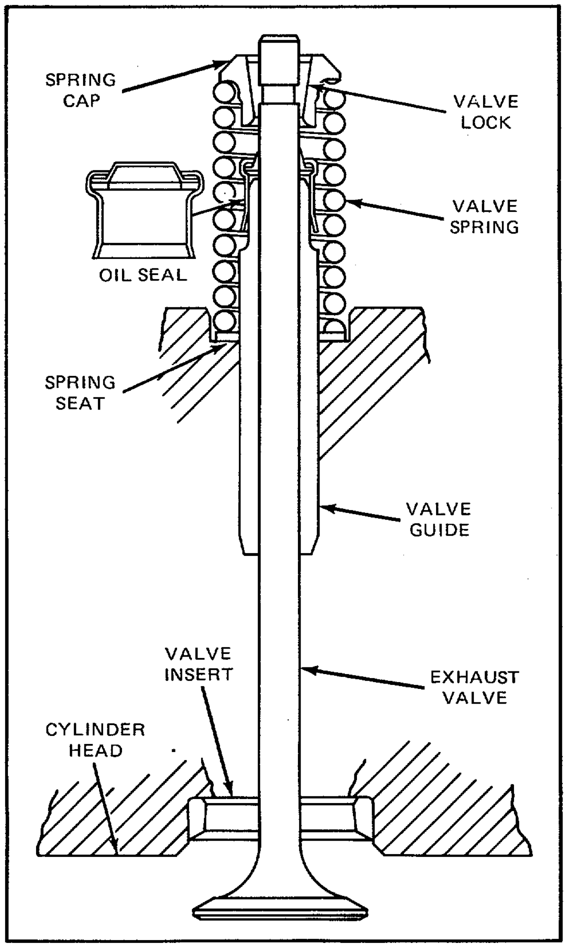


Figure 17. Current Valve Guide Oil Seal

5. Install the valve springs and valve spring caps.
6. Thread the valve spring compressor J 7455 into one of the rocker shaft boltholes in the cylinder head (Fig. 2).
7. Apply pressure to the free end of the tool to compress the valve spring and install the two-piece tapered valve lock. Exercise care to avoid scoring the valve stem with the valve cap when compressing the spring.

CAUTION

If valve guide oil seals are used, compress the valve spring only enough to permit installation of the valve locks. Compressing the spring too far may result in damage to the oil seal.

8. Release the tool and install the valve locks on the remaining exhaust valves in the same manner.
9. Check the position of the exhaust valve (Fig. 13).
10. Support the cylinder head at each end with woodblocks and remove the masking tape so that the exhaust valves are free. Then give the ends of the valve stem a sharp tap with a plastic hammer to seat the valve locks. This will aid in the proper seating of the valve locks and reduce the chances of failure.
11. With the exhaust valves installed in the cylinder head, use spring checking gage J 25076-01 and note the gage reading the moment the exhaust valve starts to open (Fig. 18). The minimum pressure required to start to open the exhaust valve must not be less than 33 pounds for a two-valve cylinder head or 25 pounds for a four-valve cylinder head.
12. Install the injectors, rocker arms, shafts, brackets, and any other parts that were previously removed from the cylinder head.
13. Install the cylinder head. Refer to *Preinstallation Inspection* and *Install Cylinder Head*.
14. Perform a complete engine tuneup.

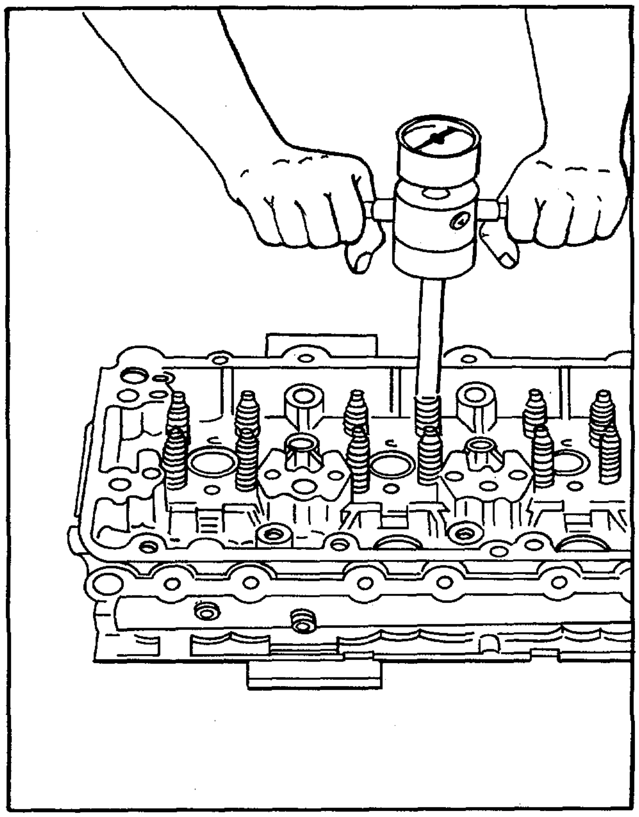


Figure 18. Checking Valve Opening Pressure with Gage J 25076-01

VALVE ROCKER COVER

The valve rocker cover assembly (Fig. 1) completely encloses the valve and injector rocker arm compartment at the top of the cylinder head. The top of the cylinder head is sealed against oil leakage by a gasket located in the flanged edge of the cover.

An option plate is inserted in a retainer (Fig. 1) attached to the cover on each in-line engine.

The valve rocker cover assembly on certain engines may include a breather assembly or an oil filler, depending upon the engine application.

Remove and Install Valve Rocker Cover

Clean the valve rocker cover before removing it from the engine to avoid dust or dirt from entering the valve mechanism. Then remove the -valve cover screws and lift the cover straight up from the cylinder head. Use a new gasket when reinstalling the cover.

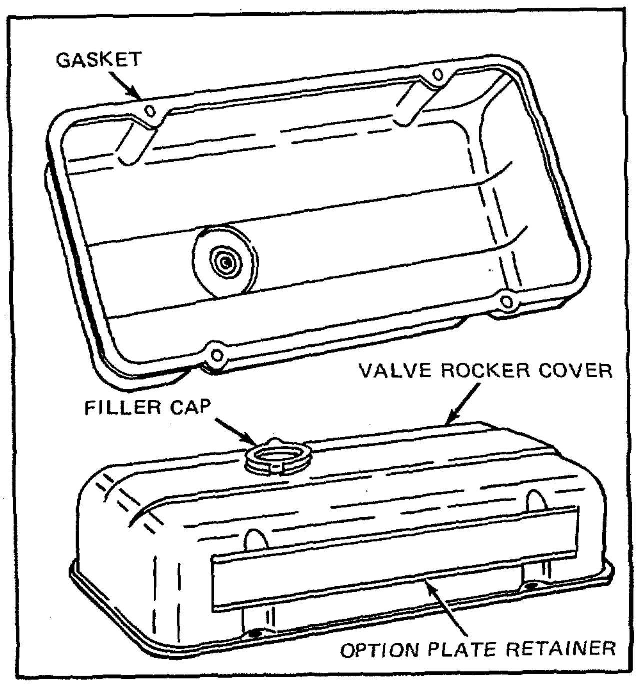


Figure 1. Typical Valve Rocker Cover Assembly

CRANKSHAFT

The crankshaft (Fig. 1) is a one-piece steel forging, heat-treated to ensure strength and durability. All main and connecting rod bearing journal surfaces, oil seal surfaces and fillets on 4-53 vehicle engine crankshafts are induction hardened.

Complete static and dynamic balance of the crankshaft has been achieved by counterweights incorporated in the crankshaft.

The crankshaft end play is controlled by thrust washers located at the rear main bearing cap of the engine. Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block.

On certain 4-53 engines, a crankshaft with splines at the front end is used. These engines use a splined crankshaft pulley and pulley mounting components.

Remove Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Clean the exterior of the engine.

2. Drain the cooling system.

3. Drain the engine crankcase.

4. Remove all engine to base attaching bolts. Then, with a chain hoist and sling attached to the lifter brackets at each end of the engine, remove the engine from its base.

5. Remove all of the accessories and assemblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand.

6. Mount the engine on an overhaul stand and fasten it securely to the mounting plate.

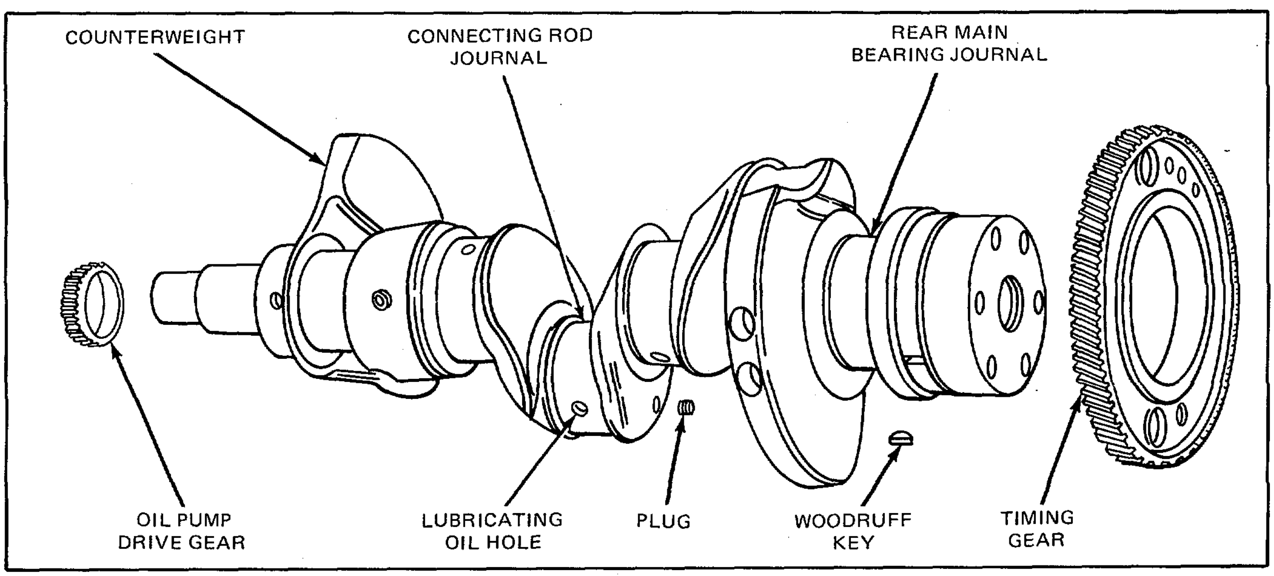


Figure 1. Crankshaft Details and Relative Location of Parts (Three-Cylinder In-Line Engine Crankshaft Shown)

WARNING

Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

7. Remove the oil pan.
8. Remove the oil pump inlet pipe and screen.
9. Remove the flywheel and flywheel housing.
10. Remove the crankshaft pulley.
11. Remove the front engine support.
12. Remove the engine lower front cover and oil pump assembly.
13. Remove the cylinder head(s).
14. On the V-type engines, remove the main bearing cap stabilizers.
15. Remove the connecting rod bearing caps.
16. Remove the main bearing caps.
17. Remove the thrust washers from each side of the rear main bearing.
18. Remove the pistons, connecting rods, and liners.
19. Remove the crankshaft, including the timing gear (Fig. 2).
20. Refer to *Timing Gear* for removal of the crankshaft timing gear and *Oil Pump* for the procedure covering removal of the oil pump drive gear.

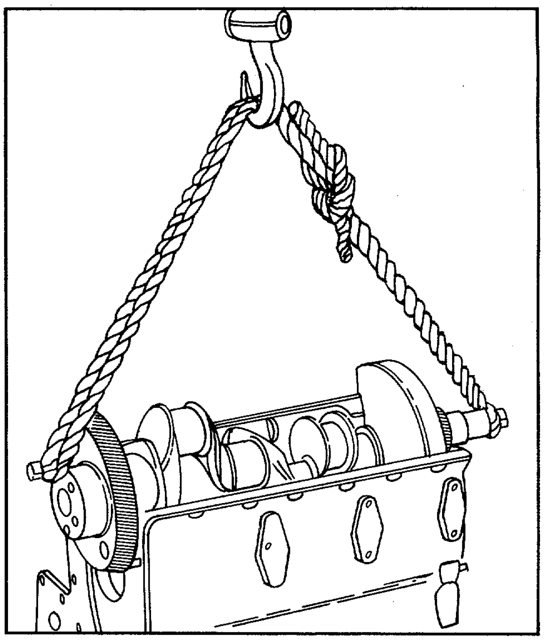


Figure 2. Removing or Installing Crankshaft

Inspection

After the crankshaft has been removed, clean and inspect it thoroughly before reinstalling it in the engine.

Remove the plugs and clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air. Then reinstall the plugs.

Inspect the keyways for evidence of cracks or wear. Replace the crankshaft, if necessary.

If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.

Used crankshafts will sometimes show a certain amount of ridging caused by the groove in the upper main bearing shell or lower connecting rod bearing shell (Fig. 3). Ridges exceeding 0.0002 inch must be removed. If the ridges are not removed, localized high-unit pressures on new bearing shells will result during engine operation.

The ridges may be removed by working crocus cloth, wet with fuel oil, around the circumference of the crankshaft journal. If the ridges are greater than 0.0005 inch, first use 120-grit emery cloth to clean up the ridge, 240-grit emery cloth for finishing, and wet crocus cloth for polishing. Use of a piece of rawhide or other suitable rope wrapped around the emery cloth or crocus cloth and drawn back and forth will minimize the possibility of an out-of-round condition developing (keep the strands of rawhide apart to avoid bind). If rawhide or rope is not used, the crankshaft should be rotated at intervals. If the ridges are greater than 0.001 inch, the crankshaft may have to be reground.

Carefully inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surface will result in oil leakage at this point.

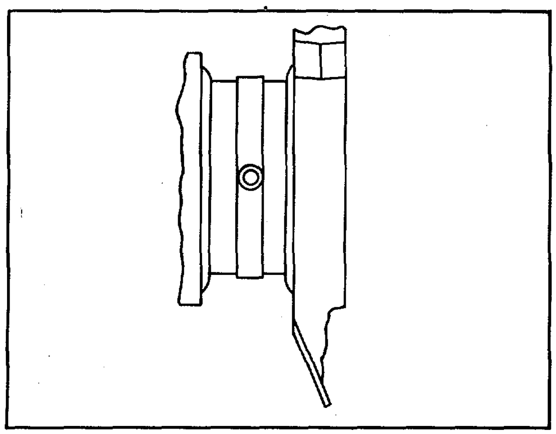


Figure 3. Typical Ridging of Crankshaft

Slight ridges on the crankshaft oil seal contact surface may be cleaned up with emery cloth and crocus cloth in the same manner as detailed for the crankshaft journals. If the crankshaft cannot be cleaned up satisfactorily, the oil seal may be repositioned in the flywheel housing and front cover as outlined in *Crankshaft* and *Oil Seals*.

Check the crankshaft thrust surfaces for excessive wear or grooving. If only slightly worn, the surfaces may be dressed with a stone. Otherwise it will be necessary to regrind the thrust surfaces.

Check the oil pump drive gear and the crankshaft timing gear for worn or chipped teeth. Replace the gears if necessary.

Inspect the crankshaft for cracks as outlined under *Inspection for Cracks*.

Crankshaft Measurements

Support the crankshaft on its front and rear journals on V-blocks or in a lathe, and check the alignment at the adjacent intermediate main journals with a dial indicator.

On 4-cylinder in-line crankshafts, the maximum runout on the intermediate journals must not exceed 0.002 inch total indicator reading.

Measure all of the main and connecting rod bearing journals (Fig. 6). Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod journal-to-bearing shell clearance (with new shells) exceeds 0.0045 inch or the main bearing journal-to-bearing shell clearance (with new shells) exceeds 0.0040 inch, the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest O.0002 inch. Also, if the journal taper or the out-of-round is greater than 0.003 inch, the crankshaft must be reground.

Also measure the crankshaft thrust surfaces (Fig. 8).

Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oilhole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be rejected. Several methods of determining the presence of minute cracks not visible to the eye are outlined below.

Magnetic Particle Method: The part is magnetized and then covered with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack. The crankshaft must be demagnetized after the test.

Fluorescent Magnetic Particle Method: This method is similar to the magnetic particle method, but is more sensitive since it employs magnetic particles which are fluorescent and glow under black light. Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the black light.

Fluorescent Penetrant Method: This is a method which may be used on both nonmagnetic and magnetic materials. A highly fluorescent, liquid penetrant is applied to the part. Then the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under black light.

Nonfluorescent Penetrant Method: The test area being inspected is sprayed with Spotcheck or Dye Check. Allow 1 to 30 minutes to dry. Remove the excess surface penetrant with clean cloths premoistened with cleaner/ remover. DO NOT FLUSH SURFACE WITR CLEANER/REMOVER because this will impair sensitivity. Repeat this procedure with additional wipings until residual surface penetrant has been removed. Shake developer thoroughly until agitator rattles. Invert spray can and spray short bursts to clear valve. Then spray this even developer film evenly over the test area being inspected. Allow developer film to dry completely before inspecting. Recommended developing time is 5 to 15 minutes.

The above methods provide basic instructions. Specific details should be obtained from the supplier of the equipment or material.

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure.

Interpretation of the indications is the most important step.

All Detroit Diesel crankshafts are magnetic particle inspected after manufacture to ensure against any shafts with harmful indications getting into the original equipment or factory parts stock.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service: a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load (Fig. 4).

Bending fatigue failures result from bending of the crankshaft which takes place once per revolution.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, a loose or broken bearing cap, or unbalanced pulleys. Also, drive belts which are too tight may impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

Torsional fatigue failures result from torsional vibration which takes place at high frequency.

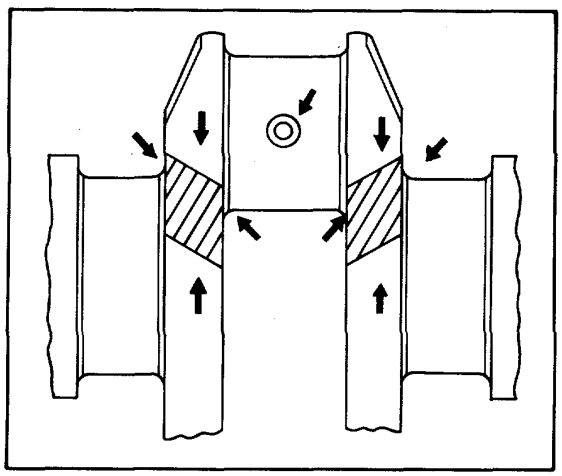


Figure 4. Critical Crankshaft Loading Zones

A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations shown in Fig. 4.

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek. Connecting rod journal failures are usually at the fillet at 45° to the axis of the shaft.

A loose, damaged, or defective vibration damper, a loose flywheel, or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or resetting the governor at a different speed than intended for the engine application may be contributory factors.

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° with the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal oilholes as shown in Fig. 5. Replace the crankshaft when cracks of this nature are found.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, 0.002, 0.010, 0.020, and 0.030 inch undersize bearings are available.

NOTE

The 0.002 inch undersize bearings are used only to compensate for slight wear on crankshafts on which regrinding is unnecessary.

If the crankshaft is to be reground, proceed as follows:

1. Compare the crankshaft journal measurements taken during inspection with the dimensions in Table 1 and Fig. 6 and determine the size to which the journals are to be reground.

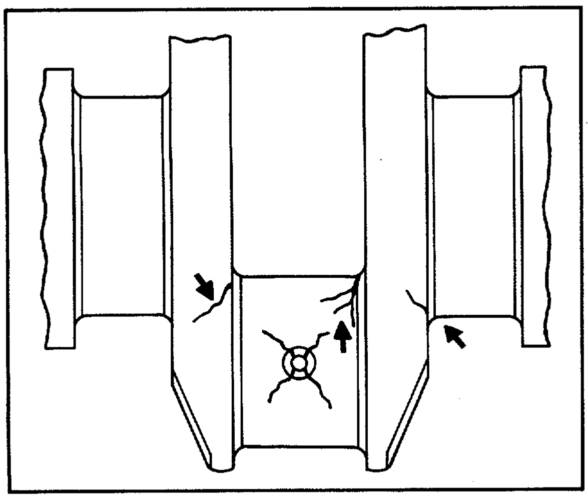


Figure 5. Crankshaft Fatigue Cracks

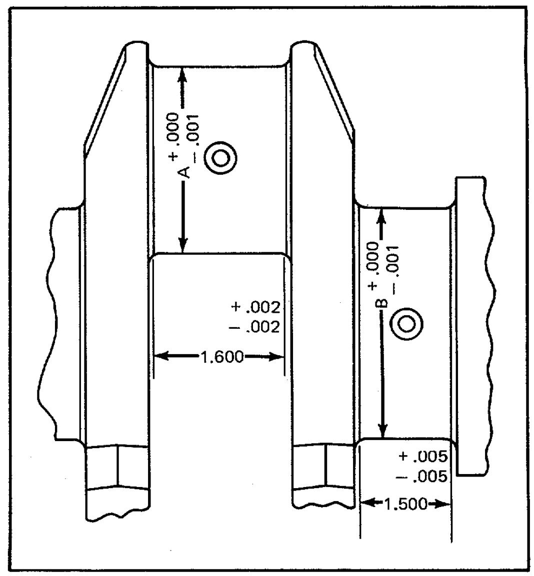


Figure 6. Dimensions of Crankshaft Journals - In-Line Engine

2. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.

3. All journal fillets in the inline crankshafts must have a 0.130 to 0.160 inch radius between the crank cheek and the journal and must not have any sharp grind marks (Fig. 7). The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches. The radius may be checked with a fillet gage.

4. Care must be taken to avoid localized heating which often produces grinding cracks. Cool the crankshaft while grinding, using coolant generously. Do not crowd the grinding wheel into the work.

5. Polish the ground surfaces to an 8-12 rms finish. The reground journals will be subject to excessive wear unless polished smooth.

Bearing Size	Conn. Rod Journal Dia.	Main Bearing Journal Dia.
In-Line Engines		
Standard	2.499-2.500 inches	2.999-3.000 inches
0.002 inch Undersize	2.497-2.498 inches	2.997-2.998 inches
0.010 inch Undersize	*2.489-2.490 inches	*2.989-2.990 inches
0.020 inch Undersize	*2.479-2.480 inches	*2.979-2.980 inches
0.030 inch Undersize	*2.469-2.470 inches	*2.969-2.970 inches

*Dimension of reground crankshaft

TABLE 1

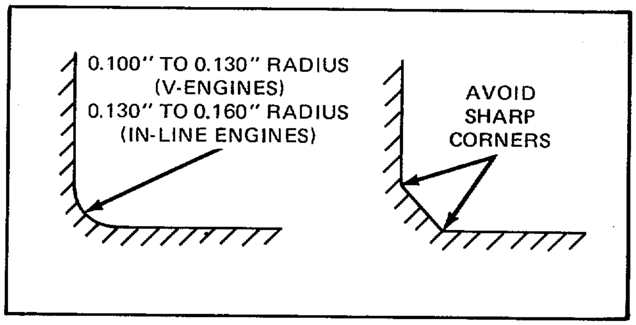


Figure 7. Crankshaft Journal Fillets

6. If the thrust surfaces of the crankshaft (Fig. 8) are worn or grooved excessively, they must be reground and polished. Care must be taken to leave a 0.130 to 0.160-inch radius on the inline crankshaft between each thrust surface and the bearing journal.

7. Stone the edge of all oilholes in the journal surfaces smooth to provide a radius of approximately 3/32 inch.

8. After grinding has been completed, inspect the crankshaft by the magnetic particle method to determine whether cracks have originated due to the grinding operation.

9. Demagnetize the crankshaft.

10. Remove the plugs and clean the crankshaft and oil passages thoroughly with fuel oil. Dry the shaft with compressed air and reinstall the plugs.

Install Crankshaft

If a new crankshaft is to be installed, steam clean it to remove the rust preventive, blow out the oil passages with compressed air, and install the plugs. Then install the crankshaft as follows:

1. Assemble the crankshaft timing gear (*Timing Gears*) and the oil pump drive gear (*Lubricating Oil Pump*) on the crankshaft.

2. Refer to main bearing for details and install the upper grooved main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

CAUTION

When a new or reground crankshaft is installed, ALL new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

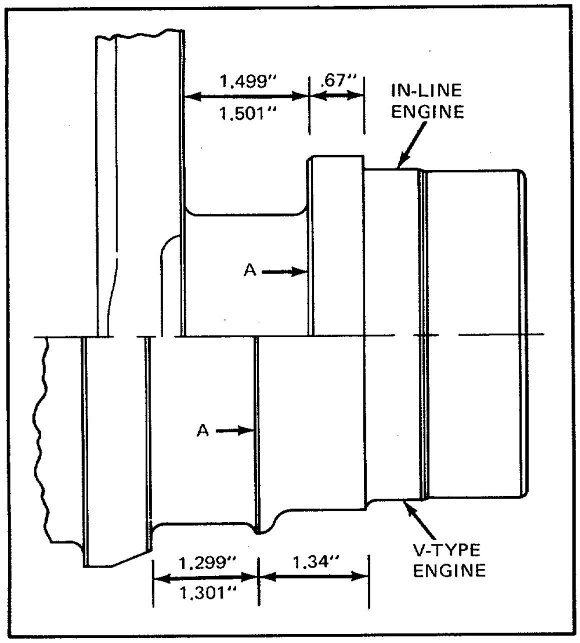


Figure 8. Standard Dimensions at Crankshaft Thrust Surfaces - In-Line and V-Type Engines

3. Apply clean engine oil to all crankshaft journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the idler gear match. Refer to *Gear Train and Timing* for the correct method of timing the gear train.

4. Install the upper halves of the crankshaft thrust washers on each side of the rear main bearing support and the doweled lower halves on each side of the rear main bearing cap. The grooved side of the thrust washers must face toward the crankshaft thrust surfaces.

CAUTION

If the crankshaft thrust surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the rear main journal. Refer to Fig. 8 and Table 2.

5. Install the lower bearing shells (no oil grooves) in the bearing caps. If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

6. Install the bearing caps and lower bearing shells as outlined under *Install Main Bearing Shells*.

NOTE

If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

7. Check the crankshaft end play by moving the crankshaft toward the gage (Fig. 9) with a pry bar. Keep a constant pressure on the pry bar and set the dial indicator to zero. Then

TABLE 2

Nominal Size	Thrust Washer Thickness	
	Min.	Max.
Standard	0.1190 inch	0.1220 inch
0.005 inch Oversize	0.1240 inch	0.1270 inch
0.010 inch Oversize	0.1290 inch	0.1320 inch

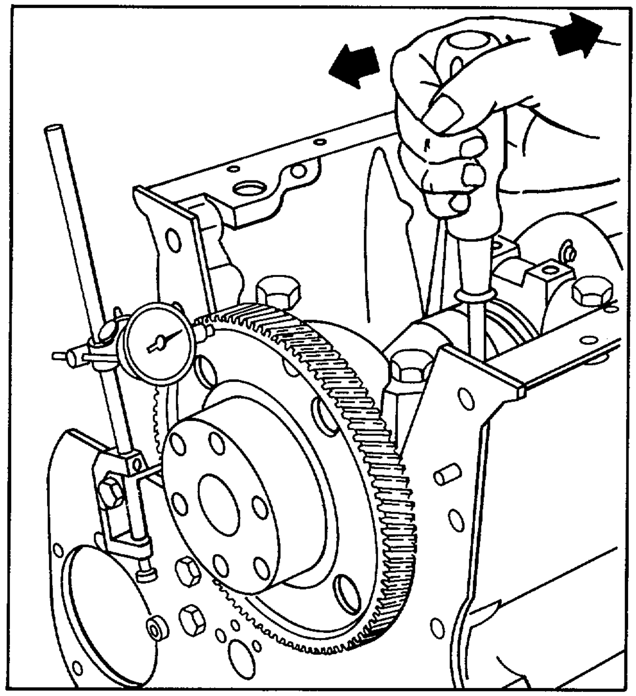


Figure 9. Checking Crankshaft End Play

remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be 0.004 to 0.011 inch with new parts or a maxi- mum of 0.018 inch with used parts. Insufficient end play can be the result of a misaligned rear main bearing or a burr or dirt on the inner face of one or more of the thrust washers.

8. Install the cylinder liner, piston, and connecting rod assemblies (*Cylinder Liner*).
9. Install the cylinder head(s) (*Cylinder Head*).
10. Install the flywheel housing (Flywheel Housing), then install the flywheel (*Flywheel).*
11 Install the crankshaft lower engine front cover and oil pump assembly on in-line engines.
12. Install the engine front support, if used.
13. Install the crankshaft pulley (Crankshaft Pulley).
14. Install the oil pump inlet pipe and screen on in-line engines.
15. Check the crankshaft for distortion (bending) at the rear connecting rod journal counterweights before and after installing a transmission. If improperly installed, these components can distort the crankshaft and cause a crankshaft malfunction.

CAUTION

Overtightened drive belts can also cause crankshaft distortion. Refer to Lubrication and Preventive Maintenance for recommended belt tension.

IMPORTANT

The part attached should not decrease crankshaft end play. While in each case one must be guided by the individual circumstances and facts that evolve, generally speaking Detroit Diesel Allison cannot be responsible for system damage caused by engine-to-driven component interference and/or distortion. Consequently, the engine crankshaft end play check and crankshaft distortion check are MUSTS.

Check the crankshaft distortion as follows:

a. Rotate the crankshaft clockwise until the crankshaft counterweights at the rear connecting rod journal are in the 6 o'clock position.

b. Center punch a hole in the in- side face of each counterweight cheek, one quarter of an inch from the lower end of each counterweight, to support the gage.

c. Install a gage (Starrett Co. No. 696 dial gage, or equivalent) in the center punch holes in the cheek of each counterweight as shown in Fig. 10.

d. Set the dial indicator at zero, then rotate the crankshaft approximately 90° in both directions. Do not allow the gage to contact the connecting rod caps or bolts. Note and record the dial indicator readings at the 3, 6, and 9 o'clock crankshaft counterweight positions. The maximum allowable variation is 0.0045-inch total indicator reading.

NOTE

Remove the tool that was used to rotate the crankshaft when taking the dial indicator readings.

e. If the reading on the gage exceeds 0.0045 inch, check the trans- mission, for improper installation and realign as necessary.

16. Affix a new gasket to the oil pan flange and install the oil pan.

17. Use a chain hoist and sling attached to the lifting bracket at each end of the engine and remove the engine from the overhaul stand.

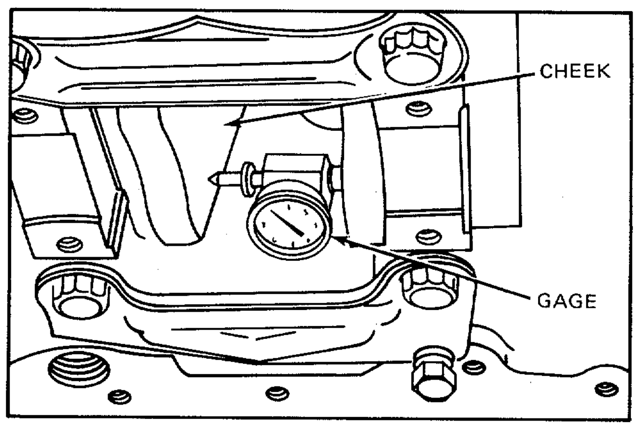


Figure 10. Crankshaft Distortion Measuring Gage Mounted on Crankshaft

18. Install all of the accessories that were removed.

19. After the engine has been completely reassembled, refer to the Lubricating Oil Specifications and refill the crankcase to the proper level on the dipstick.

20. Close all of the drains and fill the cooling system.

21. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in Run-In.

CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the oil seals are held firmly, but not tight, against the crankshaft seal- ing surfaces by a coil spring.

The front oil seal is pressed into the lower front cover on in-line engines (Fig. 1).

A single-lip oil seal is used at the rear end of the crankshaft of most industrial engines. The rear oil seal is pressed into the flywheel housing (Fig. 2).

Oil leaks indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout, or grooved sealing surfaces on the crankshaft. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

Remove Crankshaft Oil Seals

Remove the engine front cover (Engine Front Cover (Lower)), outboard bearing support or the flywheel housing (Fly- wheel Housing) and remove the oil seals as follows:

1. Support the forward face of the front cover, or the outboard bearing support, on two woodblocks next to the oil seal bore. Then press or drive the oil seal out of the front cover or the outboard bearing support. Discard the oil seal.

2. Support the forward face of the flywheel housing on in-line engines on two woodblocks next to the oil seal bore. Then press or drive the oil seal out of the housing. Discard the oil seal.

3. Clean the oil seal bore in the front cover, outboard bearing support, or flywheel housing thoroughly before installing a new oil seal.

When necessary, an oil seal may be re- moved without removing the front cover, outboard bearing support, or flywheel

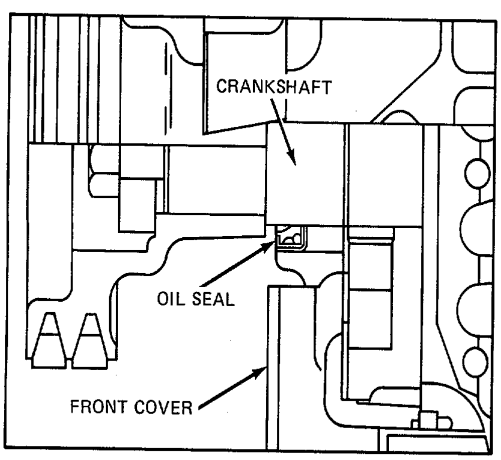


Figure 1. Crankshaft Front Oil Seal

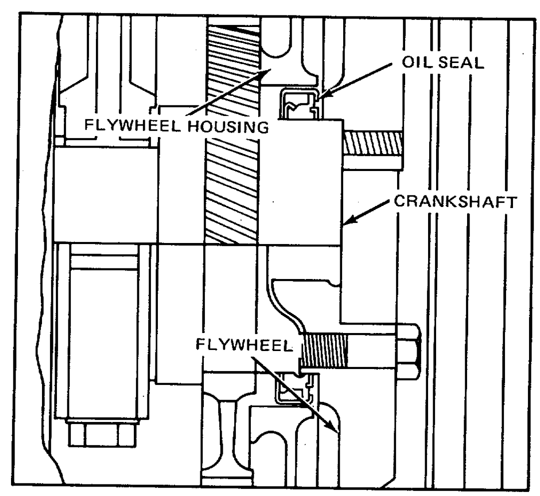


Figure 2. Crankshaft Rear Oil Seal

housing. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casting. Remove the seal by prying against the washers with pry bars.

Inspection

Inspect the front and rear end of the crankshaft for wear due to the rubbing action of the oil seal, dirt buildup, or fretting caused by action of the flywheel.

The crankshaft surface must be clean and smooth to prevent damaging the seal lip when a new oil seal is installed. Slight ridges may be removed from the crankshaft as outlined under *Inspection.*

On in-line engines, if the crankshaft cannot be cleaned up satisfactorily, the oil seal nay be pressed into the flywheel housing or the front cover 1/8 inch from its original position.

If excessive wear or grooving is pre- sent, install an oil seal sleeve (Fig. 3 & 4) which provides a replaceable wear surface for the lip-type oil seal. The oil seal sleeve may be used with either the single-lip or double-lip type oil seal, and can also be used in conjunction with the seal spacer. However, an oversize oil seal must be used with the sleeve.

Install the rear oil seal sleeve (Fig. 3) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.

2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

3. Drive the sleeve squarely on the shaft with crankshaft rear oil seal sleeve installer J 21277.

4. Wipe off any excess sealant.

5. Coat the outside diameter of the sleeve with engine oil.

Install the front oil seal sleeve (Fig. 4) as follows:

1. Stone the high spots from the oil seal contact surface of the crankshaft.

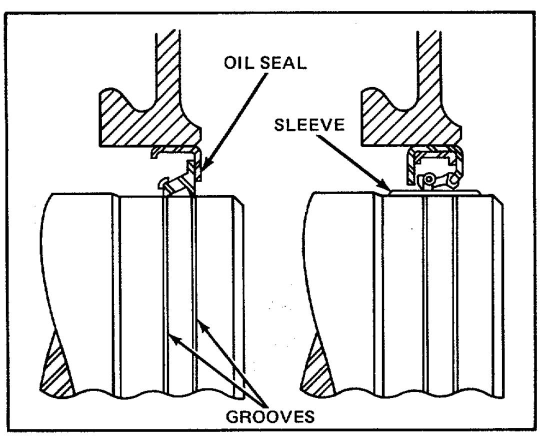


Figure 3. Use of rear Oil Seal Sleeve on Grooved Crankshaft

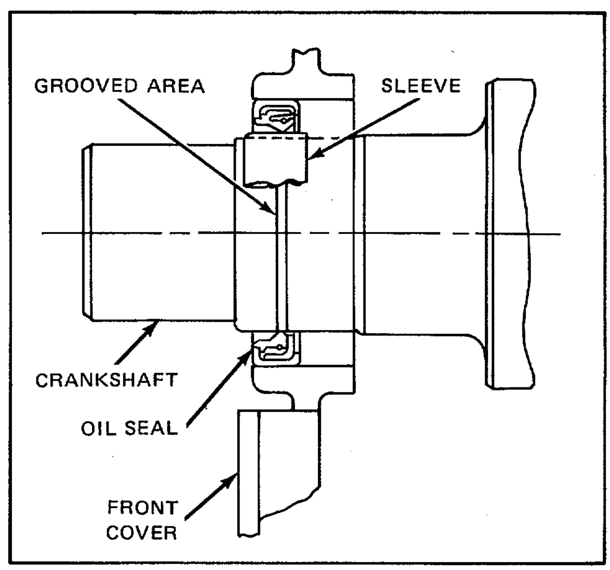


Figure 4. Use of Front Oil Sleeve on Grooved Crankshaft

2. Coat the area of the shaft where the sleeve will be positioned with shellac or an equivalent sealant.

3. Position the sleeve on the crank- shaft with the radius on the sleeve facing away from the engine.

4. Drive the sleeve squarely on the shaft with front oil seal sleeve in- staller J 22524 and the crankshaft pulley retaining bolt.

5. Wipe off any excess sealant.

6. Coat the outside diameter of the sleeve with engine oil.

NOTE

To remove a worn sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off of the end of the crank-shaft.

Oil Seals

Current oil seals are made of an oil resistant synthetic rubber which is pre-lubricated with a special lubricant. DO NOT REMOVE THIS LUBRICANT. Keep the sealing lip clean and free from scratches. In addition, a plastic coating which acts as a sealant has been applied to the outer surf ace of the casing. Do not remove this coating.

The rear oil seal may have either an open or closed back. Both types are serviced.
Install Crankshaft Front Oil Seal

1. If the oil seal is not pre-coated, apply a non-hardening sealant to the periphery of the metal casing.

2. Coat the lip of the new oil seal lightly with grease or vegetable shortening. Then position the seal in the cover or outboard bearing support with the lip of the seal pointed toward the inner face of the cover or bearing support.

3. Place the cover or outboard bearing support in an arbor press (inner face down).

4. On in-line engines, use installer J 9783 to press the oil seal into the cover until the seal is flush with the outside face of the cover.

5. Remove any excess sealant.

6. Install the engine front cover or the outboard bearing support.

Install Crankshaft Rear Oil Seal

1. Support the inner face of the flywheel housing in an arbor press or on a flat surface.

2. If the new seal is not pre-coated, apply a nonhardening sealant to the periphery of the metal casing. Then position the seal with the lip pointed toward the inner face of the housing.

3. Coat the lip of the oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double- lip seal). Do not scratch or nick the sealing edge of the oil seal.

4. Remove any excess sealant from the flywheel housing and the seal.

CAUTION

If the oil seal is of the type which incorporates a brass re- tainer in the inner diameter of the seal, be sure the retainer is in place in the seal before installing the flywheel housing on the engine. If the retainer is left out, oil leakage will result.

5. Install the flywheel housing.

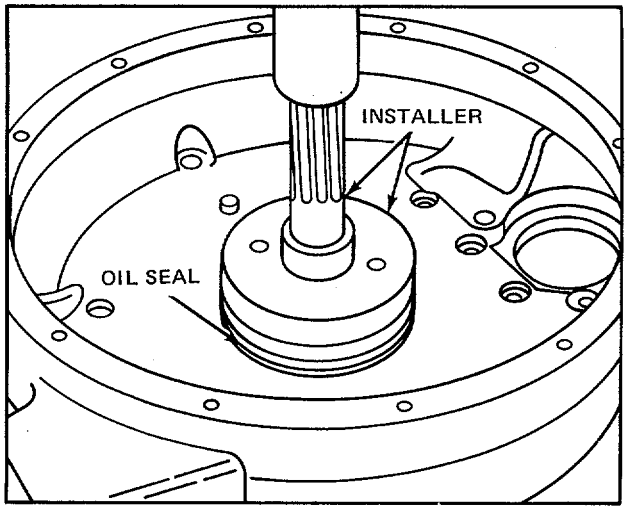


Figure 5. Installing Oil Seal in Flywheel Housing

CRANKSHAFT MAIN BEARINGS

The crankshaft main bearings shells (Fig. 1) are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell. The tangs on the lower bearing shells are off-center and the tangs on the upper bearing shells are centered to aid correct installation.

On in-line engines, a 7/16-inch oil hole in the groove of each upper bearing shell, midway between the parting lines, registers with a vertical oil passage in the cylinder block. Lubricating oil under pressure passes from the cylinder block oil gallery by way of the bearing shells to the drilled passages in the crankshaft, then to the connecting rods and connecting rod bearings.

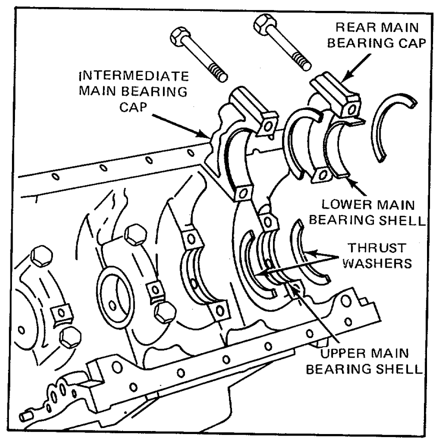


Figure 1. Main Bearing Shells, Bearing Caps, and Crankshaft Thrust Washers - In-Line Engines

The lower main bearing shells have no oil grooves; therefore, the upper and lower bearing shells must not be interchanged.

Thrust washers (Fig. 1) on each side of the rear main bearing, absorb the crankshaft thrust. The lower halves of the two-piece washers are doweled to the bearing cap; the upper halves are not doweled.

Main bearing trouble is ordinarily indicated by low or no oil pressure. All of the main bearing load is carried on the lower bearings; therefore, wear will occur on the lower bearing shells first. The condition of the lower bearing shells may be observed by removing the main bearing caps.

If main bearing trouble is suspected, remove the oil pan, then remove the main bearing caps, one at a time (as outlined below), and examine the bearing shells.

Remove Main Bearing Shells (Crankshaft in Place)

The bearing caps are numbered 1, 2, 3, etc., indicating their respective positions and, when removed, must always be reinstalled in their original position.

All crankshaft main bearing journals, except the rear journal, are drilled for an oil passage. Therefore, the procedure for removing the upper bear- ing shells with the crankshaft in place is somewhat different on the drilled journals than on the rear journal.

Remove the main bearing shells as follows:

1. Drain and remove the oil pan to expose the main bearing caps.

2. Remove the oil pump and the oil inlet pipe and screen assembly.

3. Remove one main bearing cap at a time and inspect the bearing shells as outlined under Inspection. Reinstall each bearing shell and bearing cap before re-moving another bearing cap:

a. To remove all except the rear main bearing shell, insert a 1/4 x 3/4-inch long bolt with a 1/2-inch diameter and 1/16-inch thick head (made from a standard bolt) into the crank- shaft journal oilhole. Then revolve the shaft to the right (clockwise) and roll the bearing shell out of position as shown in Fig. 2. The head of the bolt must not extend beyond the outside diameter of the bearing shell.

b. Remove the rear main bearing upper shell by tapping on the edge of the bearing with a small curved rod, revolving the crankshaft at the same time to roll the bearing shell out as shown in Fig. 3.

c. The lower halves of the crank- shaft thrust washers will be removed along with the rear main bearing cap. The upper halves of the washers can be removed for inspection by pushing on the ends of the washers with a small rod, forcing them around and out of the main bearing support.

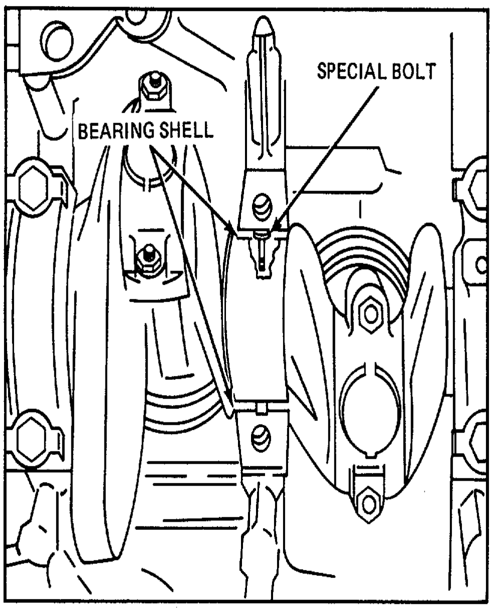


Figure 2. Removing Upper Main Bearing Shell (Except Rear Main)

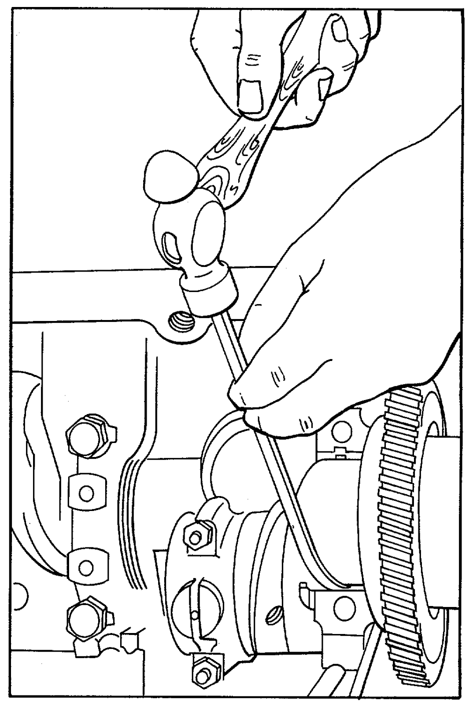


Figure 3. Removing Upper Rear Main Bearing Shell

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulfur are present which cause acid etching, flaking, and pitting.

Bearing seizure may be due to low oil or no oil.

Check the oil filter elements and re- place them if necessary. Also check the oil bypass valve to make sure it is operating freely.

Af ter removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, loss of babbitt, or signs of overheating (Fig. 4). The lower bearing shells, which carry the load, will normally show signs of dis- tress before the upper bearing shells.

Inspect the backs of the bearing shells for bright spots which indicate they have been moving in the bearing caps or bearing supports. If such spots are present, discard the bearing shells.

Measure the thickness of the bearing shells at point C, 90° from the parting line, as shown in Fig. 5 and 6. Tool J 4757, placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball.

This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is .1230 inch and, if any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of .1245 to .1250 inch.

In addition to the thickness measure- ment, check the clearance between the main bearings and the crankshaft journals. This clearance may be deter- mined with the crankshaft in place by means of a soft plastic measuring strip which is squeezed between the journal and the bearing (refer to Shop Notes). With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells Figure 4. Comparison of Main Bearing Shells

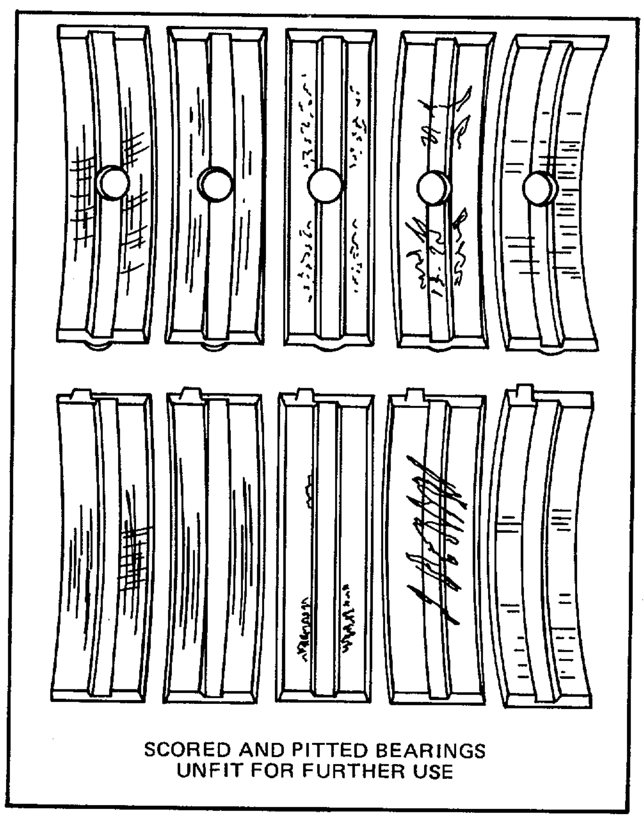


Figure 4. Comparison of Main Bearing Shells

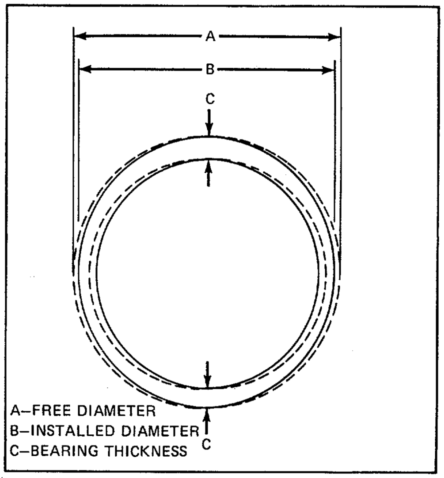


Figure 5. Main Bearing Measurements

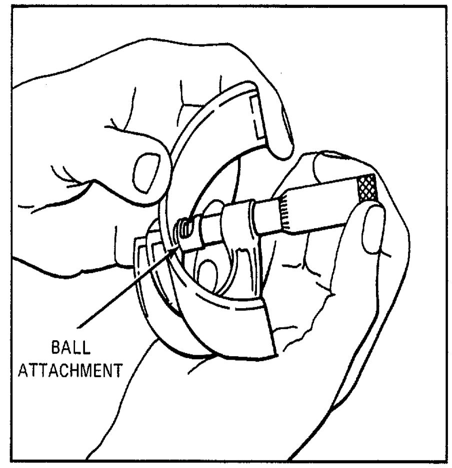


Figure 6. Measuring Thickness of Bearing Shell

installed in place with the proper torque on the bearing cap bolts. When installed, the bearing shells are 0.001 inch larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle when not installed. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This crush assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds 0.0060 inch, all of the bearing shells must be discarded and replaced. This clearance is 0.0010 to 0.0040 inch with new parts.

Before installing new replacement bear- ings, it is very important to thoroughly inspect the crankshaft journals. Very often, after prolonged engine operation, a ridge is formed on the crankshaft journals in line with the journal oilholes. If this ridge is not removed before the new bearings are installed, then, during engine operation, localized high unit pressures in the center area of the bearing shell will cause pitting of the bearing surface. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to Crankshaft Inspection for removal of ridges and inspection of the crankshaft.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

Bearing shells are available in 0.010, 0.020 and 0.030 inch undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding*. Bearing which are 0.002 inch undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

Bearing Size	Bearing Thickness	Minimum Thickness
In-Line Engines		
Standard	0.1245-0.1250 inch	0.1230 inch
0.002 inch Undersize	0.1255-0.1260 inch	0.1240 inch
0.010 inch Undersize	0.1295-0.1300 inch	0.1280 inch
0.020 inch Undersize	0.1345-0.1350 inch	0.1330 inch
0.030 inch Undersize	0.1395-0.1400 inch	0.1380 inch

TABLE 1

CAUTION

Bearing shells are NOT reworkable from one undersize to an- other under any circumstances.

Inspect the crankshaft thrust washers. If the washers are scored or worn excessively or the crankshaft end play is excessive, they must be replaced. Improper clutch adjustment can contribute to excessive wear on the thrust washers. Inspect the crankshaft thrust surfaces. Refer to *Install Crankshaft*. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the rear main bearing. A new standard size thrust washer is 0.1190 to 0.1220 inch thick. Thrust washers are available in 0.005 inch and 0.010 inch oversize.

Install Main Bearing Shells (Crankshaft in Place)

Make sure all of the parts are clean. Then apply clean engine oil to each crankshaft journal and install the upper main bearing shells by reversing the sequence of operations given for removal.

The upper and lower main bearing shells are not alike: the upper bearing shell is grooved and drilled for lubrication; the lower bearing shell is not. Be sure to install the grooved and drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps, otherwise the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.

1. When installing an upper main bearing shell with the crankshaft in place, start the plain end of the bearing shell around the crankshaft journal so that, when the bearing is in place, the tang will fit into the groove in the bearing support.

2. Install the lower main bearing shell so that the tang on the bearing fits into the groove in the bearing cap.

3. Assemble the crankshaft thrust washers (Fig. 7) before installing the rear main bearing cap. Clean both halves of each thrust washer carefully and remove any burrs from the washer seats; the slightest burr or particle of dirt may decrease the clearance between the washers and the crankshaft beyond the specified limit. Slide the upper halves of the thrust washers into place. Then assemble the lower halves over the dowel pins in the bearing cap.

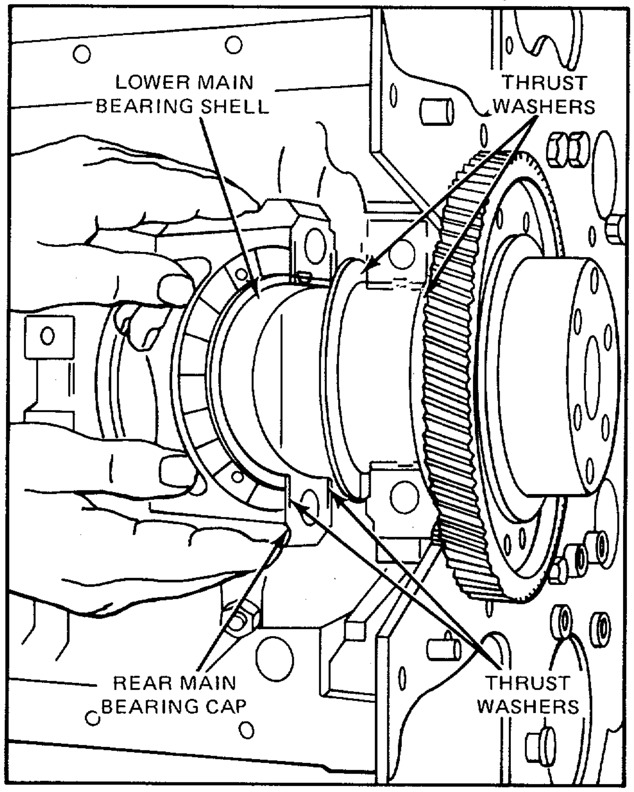


Figure 7. Crankshaft Thrust Washers in Place

CAUTION

The main bearing caps are bored in position and stamped 1, 2, 3, etc. They must be installed in their original positions with the marked side of each cap facing the same side of the cylin- der block that carried the engine serial number.

4. With the lower main bearing shells installed in the bearing caps, apply a small quantity of International Compound No. 2, or equivalent, to the bolt threads and the bolthead contact area. Install the bearing caps and stabilizers (if used) and draw the bolts up snug. Then rap the caps sharply with a soft hammer to seat them properly. Tighten all bolts (except the rear main bearing bolts) to 120- 130 lb ft (163-177 Nm) torque starting with the center bearing cap bolts and working alternately towards both ends of the block. Tighten the rear main bearing bolts to 40-50 lb ft (54-68 Nm) torque. Strike both ends of the crank- shaft two or three sharp blows with a soft hammer to ensure proper position- ing of the rear main bearing cap in the block saddle. Retorque all bearing bolts to 120-130 lb ft (163-177 Nm).

NOTE

If the bearings have been in-stalled properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

5. Check the crankshaft end play as outlined under Install Crankshaft.

6. Install the lubricating oil pump and the oil inlet pipe assembly.

7. Install the oil pan, using a new gasket.

8. Fill the crankcase to the proper level on the dipstick with heavy-duty lubricating oil of the recommended grade and viscosity (refer to Lubricating Oil Specifications).

9. After installing new bearing shells, operate the engine on a run-in schedule.

ENGINE FRONT COVER (Lower)

The engine lower front cover is mounted against the cylinder block at the lower front end of the engine (Fig. 1). It serves as a housing for the crankshaft front oil seal, the lubricating oil pump, the oil pressure regulator valve, and the oil cooler bypass valve. The cleanout openings in the periphery of the current cover incorporate tapped holes and 1/2-14 threaded plugs.

On all in-line engines effective with engine serial number 4D-6027, the oil pressure regulator valve is located on the right-hand side of the engine front cover, as viewed from the front of the engine. Prior to the above engine serial number, the oil pressure regulator valve was located on the left-hand side of the front cover just below the oil cooler bypass valve.

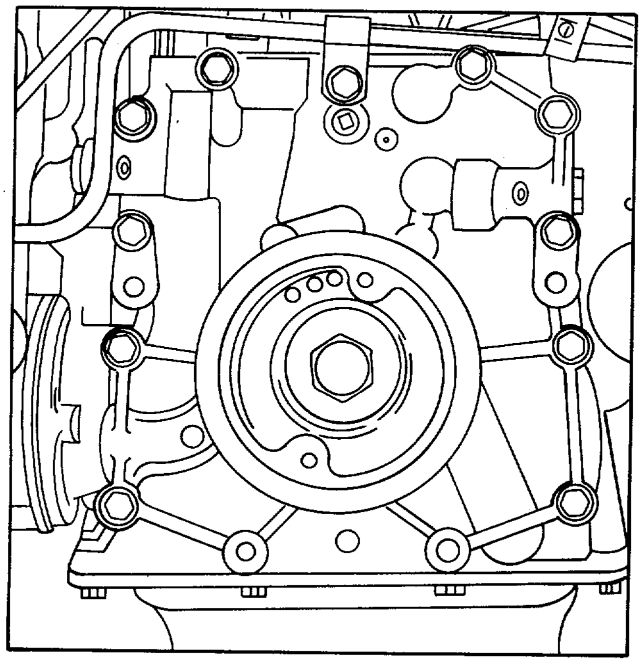


Figure 1. Engine Front Cover Mounting (Lower) - In-Line Engine Remove Engine Front Cover

1. Drain the oil and remove the oil pan.
2. Remove the crankshaft pulley as outlined in Crankshaft Pulley.
3. Remove the two bolts and lock- washers that secure the lubricating oil pump inlet tube flange or elbow to the engine front cover.
4. Remove the bolts and lockwashers that secure the engine front cover to the cylinder block.
5. Strike the cover with a soft hammer to free it from the dowels. Pull the cover straight off the end of the crankshaft.
6. Remove the cover gasket.
7. Inspect the oil seal and lubricating oil pump as outlined in Crank- shaft Oil Seals and Oil Pump. Also check the oil pressure regulator valve and oil cooler bypass valve as outlined in Oil Pressure Regulator and Lubricating Oil Cooler.

Install Engine Front Cover

1. Affix a new cover gasket to the cylinder block.
2. Install oil seal expander J 7454 over the front end of the crankshaft.
3. Thread two 3/8-16 pilot studs approximately 8 inches long into two diametrically opposite boltholes in the cylinder block to guide the cover in place (Fig. 2).
4. Apply a light coat of cup grease to the lip of the oil seal. Slide the engine front cover over the oil seal expander and pilot studs as shown in Fig. 2. Push the cover forward until the inner rotor of the oil pump

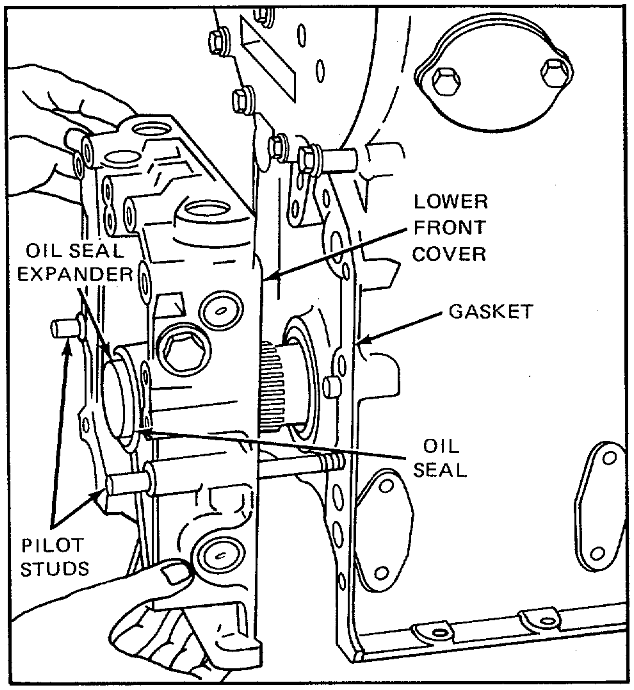


Figure 2. Installing Lower Engine Front Cover - In-Line Engine

contacts the pump drive gear on the crankshaft. Rotate the crankshaft slightly to align the teeth, then push the cover up against the gasket and block. Do not force the cover.

5. Remove the oil seal expander and pilot studs.

6. Refer to Fig. 1 and install the 3/8-16 bolts and lockwashers. Tighten the bolts to 30-35 lb ft (41-47 Nm) torque.

7. Affix a new seal ring on the end of the lubricating oil pump inlet tube next to the flange on an in-line engine. Attach the flange or elbow to the front cover with bolts and lockwashers. Tighten the bolts to 13-17 lb ft (18-23 Nm) torque.

8. Af f ix a new oil pan gasket to the bottom of the cylinder block, then install and secure the oil pan to the block with bolts and lockwashers. Tighten the bolts to 13-17 lb ft (18-23 Nm) torque.

9. Install the crankshaft pulley.

10. Refer to Lubricating Oil Specifications and refill the crankcase to the proper level on the dipstick.

CRANKSHAFT PULLEY

The crankshaft pulley is secured to the front end of the crankshaft by a special washer and a bolt. The engine application determines the type of crankshaft pulley to be used.

The appearance of the rubber bushing does not determine the condition of a rubber mounted crankshaft pulley. Check for failure of the rubber bushing by locking the crankshaft and applying pressure to the crankshaft pulley. If the pulley cannot be rotated, the bushing is in satisfactory condition. If necessary, replace the rubber bushing.

Remove Crankshaft Pulley

1. Remove the belts from the crankshaft pulley.
2. Remove the crankshaft pulley retaining bolt and special washer.
3. If a rigid-type pulley is being removed from an in-line engine, install the pulley retaining bolt and puller J 24420 as shown in Fig. 1. Then force the pulley off the crankshaft by turning the puller center screw in.

NOTE

On pulleys that do not incorporate two tapped holes in the front face of the pulley, use a two-arm, universal-type puller.

4. Remove the outer and inner cones, if used.

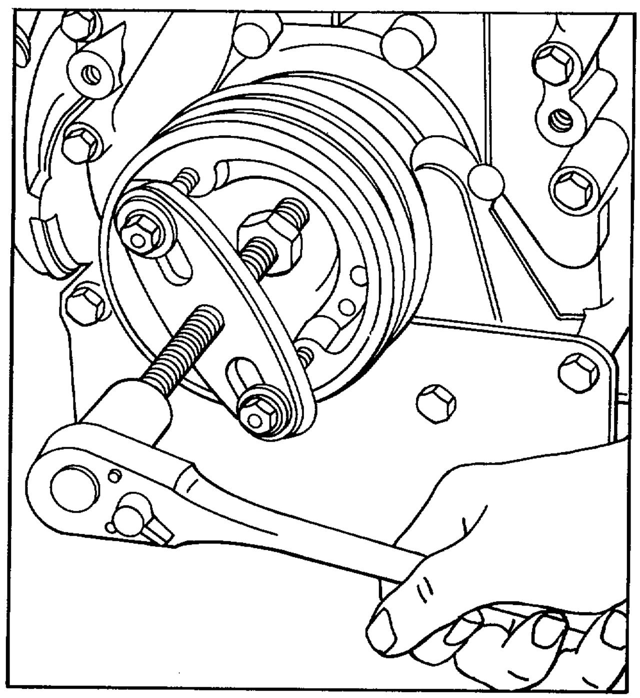


Figure 1. Removing Crankshaft Pulley Using Puller J 24420

Install Crankshaft Pulley

1. Lubricate the end of the crank- shaft with engine oil to facilitate pulley installation.
2. Slide the inner cone (Fig. 3), if used, on the crankshaft.
3. Start the pulley straight on the end of the crankshaft.
4. Install a rigid-type pulley on an in-line or 6V engine with installer J 7773 as shown in Fig. 2. Then remove the installer.
5. Slide the outer cone (Fig. 3), if used, on the crankshaft.
6. Place the washer on the crankshaft bolt and thread the bolt into the front end of the crankshaft.
7. On certain 4-53 engines, a splined crankshaft pulley is used. Place a drive flange washer over the splined end of the crankshaft. Align the splines and tap the pulley on the crankshaft with a plastic hammer. Place another drive flange washer on the bolt and thread it into the end of the crankshaft. Tighten the 3/4-16 bolt to 290-300 lb ft (393-407 Nm) torque.
8. On in-line engines with cone mounted pulleys NOT stamped with the letter A, tighten the 3/4-16 bolt to 290-300 lb ft (393-407 Nm) torque.

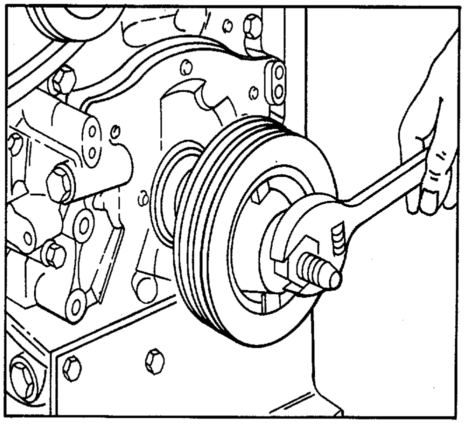


Figure 2. Installing Crankshaft Pulley Using Installer J 7773

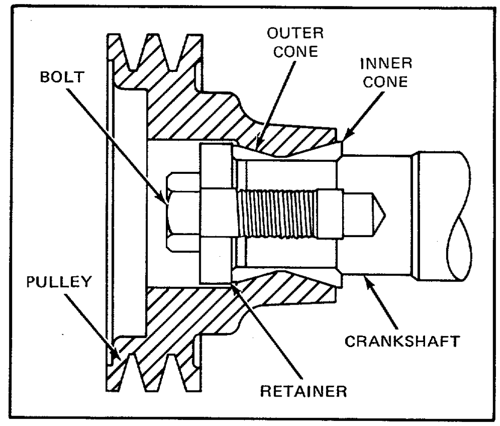


Figure 3. Cone Mounted Pulley

9. On all in-line and 6V engines with the rigid-type pulleys and cone-mounted pulleys stamped with the letter A, tighten the 3/4-16 bolt to 200-220 lb ft (271-298 Nm) torque.

10. When pulleys stamped with the letter U (in a square box) are used, tighten the 3/4-16 bolt to 290-310 lb ft (393-421 Nm) torque.

11. Install and adjust the belts.

FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with six self- locking bolts. A scuff plate is used between the flywheel and the boltheads to prevent the boltheads from scoring the flywheel surface.

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

The flywheel is machined to provide true alignment with the clutch or a power takeoff driving ring, and the center bore provides for installation of a clutch pilot bearing. The clutch or power takeoff driving ring is bolted to the flywheel.

An oil seal ring, which provides an oil-tight connection between the crankshaft and the flywheel, is fitted into a groove on flywheels used with hydraulic couplings, clutches, or Torqmatic converters.

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft, or flywheel housing. On torque converter units, the flywheel is part of the torque converter assembly and is cov- ered in the applicable converter ser- vice manual.

Remove Flywheel (Transmission Removed)

1. If a clutch housing is attached to the flywheel housing, remove the flywheel as follows:

   a. Remove the flywheel attaching bolts and the scuff plate.

   b. Lift the flywheel off the end of the crankshaft and out of the clutch housing.

2. If a clutch housing isn't used, remove the flywheel as follows: a. Remove the flywheel attaching bolts and the scuff plate while holding the flywheel in position by hand, then reinstall one bolt.

WARNING

When removing or installing the attaching bolts, hold the fly- wheel firmly against the crankshaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft.

   b. Attach flywheel lifting tool J 6361-01 to the flywheel with two 3/8-16 bolts of suitable length as shown in Fig. 1 or use tool J 25026.

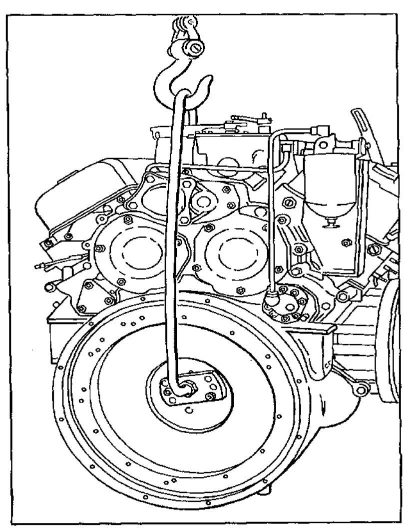


Figure 1. Removing Flywheel

c. Attach a chain hoist to the lifting tool.

d. Remove the remaining flywheel attaching bolt.

e. Move the upper end of the lifting tool in and out to loosen the flywheel, then withdraw the flywheel from the crankshaft and the flywheel housing.

f. Remove the clutch pilot bearing, if used, as outlined in Clutch Pilot Bearing.

g. Remove the oil seal ring, if used.

Inspection

Check the clutch contact face of the flywheel for scoring, overheating, or cracks. If scored, the flywheel may be refaced. However, DO NOT remove more than 0.020 inch of metal from the flywheel. Maintain all of the radii when refacing the flywheel.

Replace the ring gear if the gear teeth are excessively worn or damaged.

Check the butt end of the crankshaft and flywheel contact surface. If necessary, lightly stone the crankshaft end and the flywheel contact surface to remove any fretting or brinnelling.

On crankshafts with dowels, be sure to check the dowel extension. Dowels must not extend more than 1/2 inch (13 mm) from the crankshaft.

Make sure that the crankshaft and fly-wheel contact surfaces and the bolt threads in the crankshaft end are clean and dry, to ensure proper metal-to- metal contact and maximum friction, before attaching the flywheel.

New bolts should be used to mount or remount the flywheel. However, if the original bolts are determined to be serviceable and are to be reused, clean them thoroughly before starting the assembly procedure.

Remove Ring Gear

Note whether the ring gear teeth are chamfered. The replacement gear must be installed so that the chamfer on the teeth faces the same direction with relationship to the flywheel as on the gear that is to be removed. Then remove the ring gear as follows:

1. Support the flywheel, crankshaft side down, on a solid flat surface or a hardwood block which is slightly smaller than the inside diameter of the ring gear.

2. Drive the ring gear off the flywheel with a suitable drift and hammer. Work around the circumference of the gear to avoid binding the gear on the flywheel.

3. If a clutch pilot bearing is used, inspect the bearing and replace it, if necessary.

Install Ring Gear

1. Support the flywheel, ring gear side up, on a solid flat surface.

2. Rest the ring gear on a flat metal surface and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.

CAUTION

Do not, under any circumstances, heat the gear over 400°F (204°C); excessive heat may destroy the original heat treatment.

NOTE

Heat-indicating "crayons", which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.

4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it and apply additional heat, noting the above caution.

Install Flywheel

1. Install a new oil seal ring, if used.

2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing (use guide studs) or clutch housing. Align the flywheel boltholes with the crankshaft boltholes.

3. Install the clutch pilot bearing (if used).

4. Install two bolts through the scuff plate 180° from each other. Snug the bolts to hold the flywheel and scuff plate to the crankshaft. Remove the guide studs.

5. Remove the flywheel lifting tool.

6. Apply International Compound No. 2, or equivalent, to the threads and to the bolthead contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 and any excess wiped off.

CAUTION

International Compound No. 2 must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

7. Install the remaining bolts and run them in snug.

8. Remove the two bolts used temporarily to retain the flywheel, apply International Compound No. 2 as described above, then reinstall them.

9. Use an accurately calibrated torque wrench and tighten the bolts to 50 lb ft (68 Nm) torque.

10. Turn the bolts an additional 90°-120° (Fig. 2) to obtain the required clamping.

NOTE

Since the torque-turn method provides more consistent clamping than the former method of flywheel installation, bolt torque values should be ignored.

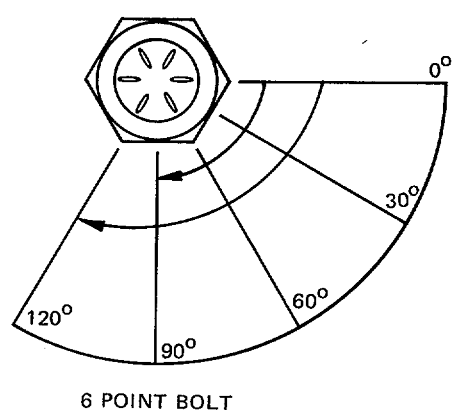


Figure 2. Torque-Turn Limits

IMPORTANT

When a clutch pilot bearing is installed, index the flywheel bolts so that the corners of the boltheads do not overlap the pilot bearing bore in the flywheel. Thus, one of the flats of each bolthead will be in line with the bearing bore. Always rotate bolts in the increased clamp direction to prevent under-clamping.

11. Mount a dial indicator on the flywheel housing and check the runout of the flywheel at the clutch contact face. The maximum allowable runout is 0.001-inch total indicator reading per inch of radius (or 0.001 mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel.

CLUTCH PILOT BEARING

The clutch pilot bearing is pressed into the bore of the flywheel assembly and serves as a support for the inner end of the clutch drive shaft.

On most applications, the clutch pilot bearing is held in place on one side by a shoulder in the flywheel and on the other side by a bearing retainer.

On certain applications, the clutch pilot bearing is held in place on one side by a bearing retainer, placed between the flywheel and the end of the crankshaft, and on the other side by the flywheel-bolt scuff plate.

Lubrication

A single-shielded ball-type clutch pilot bearing should be packed with an all-purpose grease such as Shell Alvania No. 2, or equivalent, if not previously packed by the manufacturer. A double-sealed clutch, ball-type pilot bearing is prepacked with grease and requires no further lubrication.

Remove Clutch Pilot Bearing (Transmission Removed)

With the flywheel attached to the crank- shaft, the clutch pilot bearing may be removed as follows:

1. Remove the flywheel attaching bolts and scuff plate while holding the flywheel in position by hand, then reinstall two bolts to hold the flywheel in place.

WARNING

> When removing or installing the attaching bolts, hold the flywheel firmly against the crank- shaft by hand to prevent it from slipping off the end of the crankshaft. The flywheel is NOT doweled to the crankshaft. 2. With the clutch pilot bearing remover adaptor J 23907-2 attached to slide hammer J 23907-1, insert the fingers of the adaptor through the pilot bearing and tighten the thumbscrew to expand the fingers against the inner race of the bearing.

3. Tap the slide hammer against the shoulder on the shaft and pull the pilot bearing out of the flywheel.

Inspection

Wipe the prepacked, double-sealed bearing clean on the outside and inspect it. SHIELDED BEARINGS MUST NOT BE WASHED; dirt may be washed in and the cleaning fluid could not be entirely removed from the bearing. Clean the other types of bearing thoroughly with clean fuel oil and dry them with compressed air.

Check the bearing for free rolling by holding the inner race and revolving the outer race slowly by hand. Rough spots in the bearing are sufficient cause for rejecting it.

Install Clutch Pilot Bearing

1. Lubricate the outside diameter of the bearing with clean engine oil.

2. Start the pilot bearing straight into the bore of the flywheel, with the numbered side of the bearing facing away from the crankshaft.

3. Place bearing installer J 3154-04, with suitable adapter plates, against the pilot bearing. Then drive the bearing straight into and against the shoulder in the flywheel.

4. Install the flywheel as outlined in Flywheel.

ENGINE OVERHAUL

ENGINE DRIVE SHAFT FLEXIBLE COUPLING

The engine drive shaft, flexible coupling (Fig. 1) is of the spring- loaded type having a splined hub to match with the splines on the trans- mission drive-line shaft used on certain applications. The coupling, bolted to the engine flywheel, serves as a drive and also dampens out torque fluctuations between the engine and the transmission.

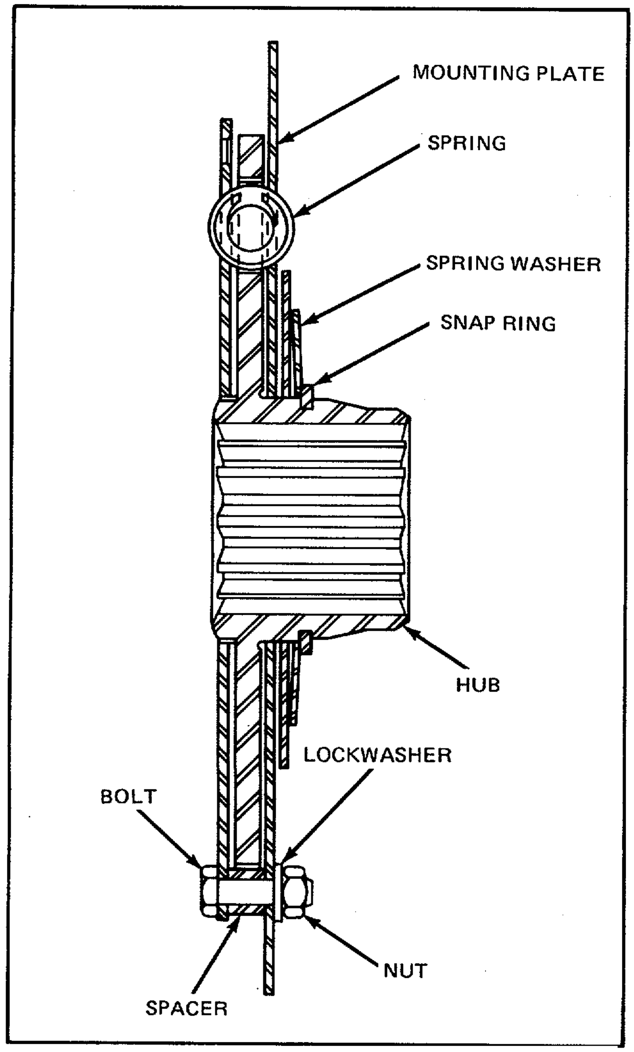


Figure 1. Engine Drive Shaft Flexible Coupling

Remove Coupling (Transmission Removed)

Remove the eight 3/8-16 x 7/8-inch long bolts which attach the coupling to the flywheel and remove the coupling.

Inspection

Wash the coupling in clean fuel oil and dry it with compressed air. Check for broken or worn springs. Springs may be replaced by removing the six bolts, lockwashers, nuts, and spacers holding the two plates together and removing the smaller plate. After replacing the springs, bolt the plates together and tighten the nuts to 25-30 lb ft (34-41 Nm) torque.

Examine the hub splines for wear and check the flatness of the mounting plate (the plate which bolts to the flywheel). Since the plates, spacers, and hubs are manufactured in matched sets, worn hubs or plates cannot be replaced individually, but must be replaced by a complete, flexible coupling assembly.

Install Coupling

Align the boltholes in the coupling with the tapped holes in the flywheel. Since one bolthole is offset, the coupling can be attached in only one position. Install the eight 3/8-16 x 7/8-inch long bolts and tighten them securely.

FLYWHEEL HOUSING

The flywheel housing is a one-piece casting, mounted against the rear cylinder block end plate, which provides a cover for the gear train and the flywheel. It also serves as a support for the starting motor and the transmission.

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing (Crankshaft Oil Seals).

Remove Flywheel Housing

1. Mount the engine on an overhaul stand as outlined in Cylinder Block.
2. Remove the starting motor from the flywheel housing or the clutch housing.
3. Remove the flywheel.
4. Remove the oil pan.
5. Remove the clutch housing, if used.
6. Remove the fuel pump, if it is mounted on the flywheel housing.
7. Remove all the bolts from the flywheel housing.

CAUTION

When removing the flywheel housing bolts, note the location of the various size bolts, lockwashers, flat washers, and copper washers so they may be reinstalled in their proper location.

8. To guide the flywheel housing until it clears the end of the crank- shaft, thread two pilot studs J 7540 into the cylinder block (Fig. 1).

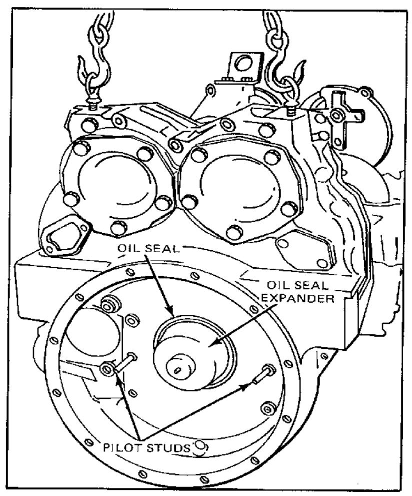


Figure 1. Removing or Installing Flywheel Housing

9. Thread eyebolts into the tapped holes in the pads (if provided) on the top or sides of the flywheel housing and attach a chain hoist with a suitable sling to the eyebolts. Then strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.

Inspection

Clean the flywheel housing and inspect it for cracks or any other damage.

IMPORTANT

It is very important that all old gasket material be thoroughly removed from the flywheel housing and the end plate, otherwise runout of the pilot and face of the housing may be affected when the housing is installed on the engine.

Remove and discard the crankshaft rear oil seal. Install a new oil seal as outlined in Crankshaft Oil Seals.

Install Flywheel Housing

1. Lubricate the gear train teeth with clean engine oil.
2. Affix a new flywheel housing gasket to the rear face of the cylinder block rear end plate. Affix the small (7/8 inch diameter) gasket near the top of the end plate.
3. If the flywheel housing has an integral cast hub, install a flywheel housing-to-end plate shim (0.015 inch thick). Use grease to hold the shim to the cylinder block rear end plate (Fig. 2).
4. Coat the lip of the crankshaft oil seal lightly with engine oil (single-lip seal) or vegetable shortening (double-lip seal). Do not scratch or nick the sealing edge of the oil seal.

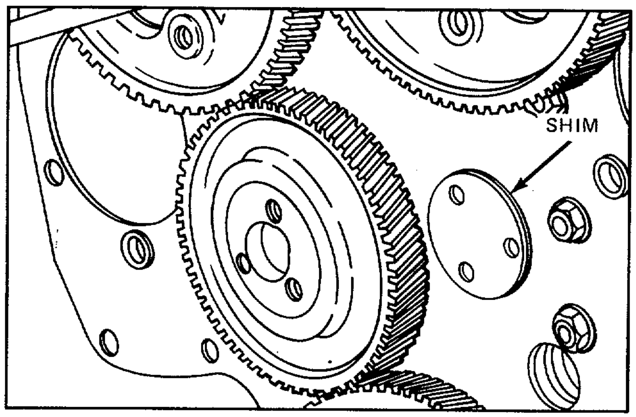


Figure 2. Location of Shim

5. Thread two pilot studs J 7540 into the cylinder block to guide the housing in place (Fig. 1). On in-line engines, to pilot the oil seal on the crankshaft successfully, use oil seal expander J 9769 (standard size seal) or J 21278-01 (oversize seal) on the end of the crankshaft.
6. With the housing suitably sup- ported, position it over the crankshaft and up against the cylinder block rear end plate and gasket(s). Remove the oil seal expander.
7. Install all the flywheel housing bolts, lockwashers, flat washers, and copper washers in their proper location, finger tight. Remove the pilot studs.

NOTE

If the engine is equipped with a clutch housing, do not install the six bolts numbered 7 through 12 (Fig. 3) until the clutch housing is installed.

8. On an in-line right-hand rotation engine, start at No. 1 and draw the bolts up snug in the sequence shown in Fig. 3.
9. Refer to Fig. 4 for the final bolt tightening sequence on an in-line engine. Then start at No. 1 and tight- en the bolts to the specified torque.
   a. Tighten the 5/16-18 bolts (No. 11 and 12) to 19-23 lb ft (26-31 Nm) torque and the 3/8-16 bolts (No. 7 through 10) to 40-45 lb ft (54-61 Nm) torque. Tighten the remaining 3/8-16 and 3/8-24 bolts to 25-30 lb ft (34-41 Nm) torque.

NOTE

Prior to Engine Serial Number 4D-103, the bolts numbered 7 through 12 in Fig. 3 were all 5/16-18 bolts and must be tightened to 19-23 lb ft (26-31 Nm) torque

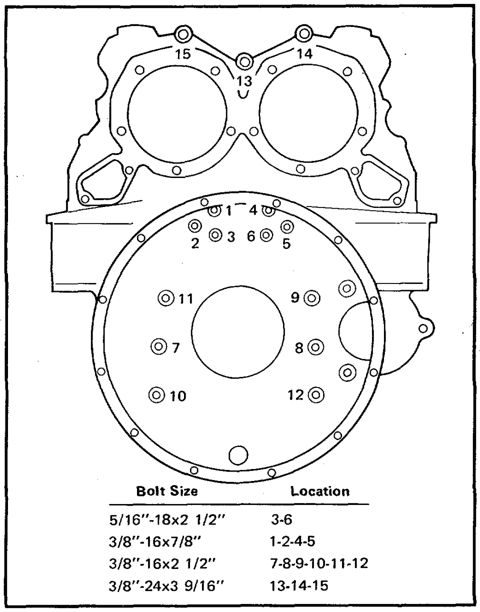


Figure 3. Flywheel Housing Bolt Sizes and Tightening Sequence (Operation 1) - In-Line Engine

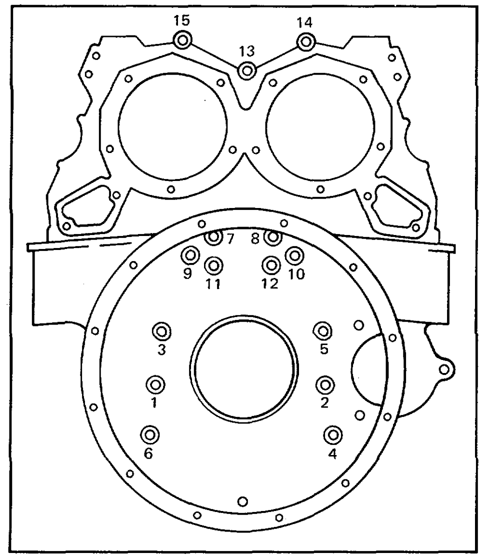


Figure 4. Flywheel Housing Bolt Tightening Sequence (Operation 2) - In-Line Engine

b. On the two-, three-, and four cylinder engines, tighten the two 5/16-18 bolts that secure the top of the governor to the flywheel housing to 10-12 lb ft (14-16 Nm) torque.

10. Install the flywheel.

11. Check the flywheel housing concentricity and bolting flange face with tool J 9737-01 as follows:

a. Refer to Fig. 5 and thread the base post J 9737-3 tightly into one of the tapped holes in the flywheel. Then assemble the dial indicators on the base post.

b. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction.

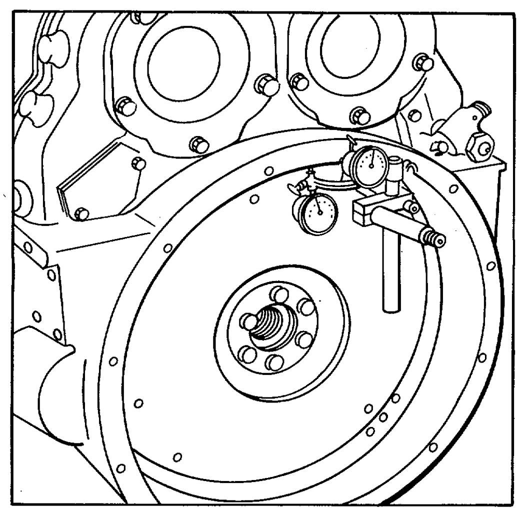


Figure 5. Checking Flywheel Housing Concentricity

NOTE

If the flywheel extends beyond the housing bell, the bore and face must be checked separately. Use the special adapter in the tool set to check the housing bore.

c. Tap the front end of the crank- shaft with a soft hammer or pry it toward one end of the block to ensure end play is in one direction only.

d. Adjust each dial indicator to read zero at the 12 o'clock position. Then rotate the crankshaft one full revolution, taking readings at 45° intervals (8 readings each for the bore and the bolting flange face). Stop and remove the wrench or cranking bar before recording each reading to ensure accuracy. The maximum total indicator reading must not exceed 0.013 inch for either the bore or the face.

e. If the runout exceeds the maximum limits, remove the flywheel housing and check for dirt or foreign material (such as old gasket material) between the flywheel housing and the end plate and between the end plate and the cylinder block.

f. Reinstall the flywheel housing and the flywheel and tighten the attaching bolts in the proper sequence and to the specified torque. Then recheck the runout. If necessary, replace the flywheel housing.

12. Install the clutch housing, if used. Tighten the 3/8-16 attaching bolts to 30-35 lb ft (41-47 Nm) torque and the 3/8-24 nuts to 35-39 lb ft (47-53 Nm) torque.

a. Install tool J 9748 in one of the crankshaft boltholes.

b. Install dial indicator J 8001-3 and position it to read the bore runout of the housing (Fig. 6). Now check the runout by rotating the crankshaft. The runout should not exceed 0.008 inch.

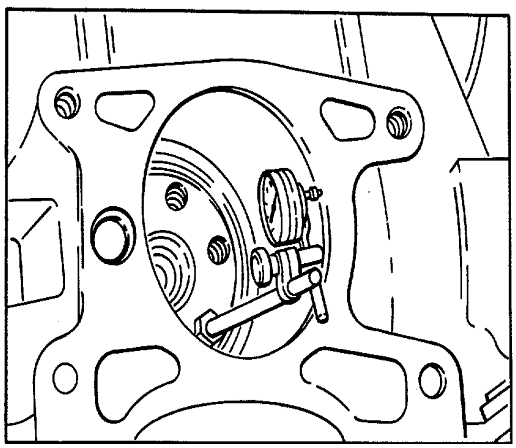


Figure 6. Checking Bore Runout

c. Reposition the dial indicator to read the face runout and rotate the crankshaft. The maximum allowable runout is 0.008 inch.

d. If the bore or face runout is excessive, loosen the housing attaching bolts and nuts slightly and tap the housing with a soft hammer in the required direction until the runout is within limits. Tighten the attaching bolts and nuts evenly to 30-35 and 35-39 lb ft (41-47 and 47-53 Nm) torque respectively. Then recheck the runout.

13. Use a new gasket and install the oil pan. Install and tighten the 1/2-13 reinforcement bolts.

14. Remove the engine from the over-haul stand and complete assembly of the engine.

PISTON AND PISTON RINGS

The trunk-type malleable iron piston (Fig. 1) is plated with a protective coating of tin which permits close fitting, reduces scuffing, and prolongs piston life. The top of the piston forms the combustion chamber bowl and is designed to compress the air into close proximity to the fuel spray.

Each piston is internally braced with fin-shaped ribs and circular struts, scientifically designed to draw heat rapidly from the piston crown and transfer it to the lubricating oil spray to ensure better control of piston ring temperature.

The piston is cooled by a spray of lubricating oil directed at the under- side of the piston head from a nozzle in the top of the connecting rod, by fresh air from the blower to the top of the piston, and indirectly by the water jacket around the cylinder.

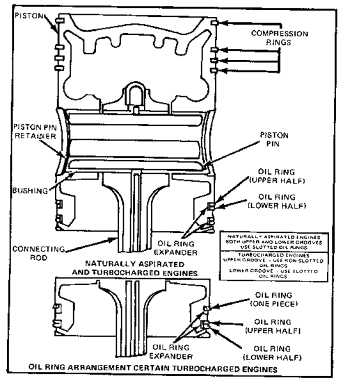


Figure 1. Typical Piston Assembly

Each piston is balanced to close limits by machining a balancing rib, provided on the inside at the bottom of the piston skirt.

Two bushings, with helical grooved oil passages, are pressed into the piston to provide a bearing for the hardened, floating piston pin (1.375 inches diameter). After the piston pin has been installed, the hole in the piston at each end of the pin is sealed with a steel retainer. Thus, lubricating oil returning from the sprayed underside of the piston head and working through the grooves in the piston pin bushings is prevented from reaching the cylinder walls.

The current piston pin retainer for the 1.375-inch diameter piston pin has a greater outside diameter (1.6110 inches) and is color-coded black for identification. The former and new retainers are interchangeable in an engine.

Each piston is fitted with compression rings and oil control rings (Fig. 1). Equally spaced drilled holes just below each oil control ring groove permits excess oil, scraped from the cylinder walls, to return to the crankcase.

The piston bushings are vapor blasted and the piston pins are polished and drilled for positive piston pin bushing lubrication.

Inspect Piston Rings

When an engine is hard to start, runs rough, or lacks power, worn or sticking compression rings may be the cause. Replacing the rings will aid in restoring engine operation to normal.

ENGINE OVERHAUL

The compression rings may be inspected through the ports in the cylinder liners after the air box covers have been removed. If the rings are free and are not worn to the extent that the plating or grooves are gone, compression should be within operating specifications. Refer to Troubleshooting (Engine) for the procedure for checking compression pressure.

Remove Piston and Connecting Rod

1. Drain the cooling system.

2. Drain the oil and remove the oil pan.

3. Remove the oil pump and inlet and outlet pipes, if necessary (Oil Pump).

4. Remove the cylinder head (Cylinder Head).

5. Remove the carbon deposits from the upper inner surface of the cylinder liner.

6. Remove the bearing cap and the lower bearing shell from the connecting rod. Then push the piston and rod assembly out through the top of the cylinder block. The piston cannot be removed from the bottom of the cylinder block.

7. Reassemble the bearing cap and lower bearing shell to the connecting rod.

Disassemble Piston and Connecting Rod

Note the condition of the piston and rings. Then remove the rings and connecting rod from the piston as follows:

1. Secure the connecting rod in a vise equipped with soft jaws and remove the piston rings with tool J 8128 as shown in Fig. 2.

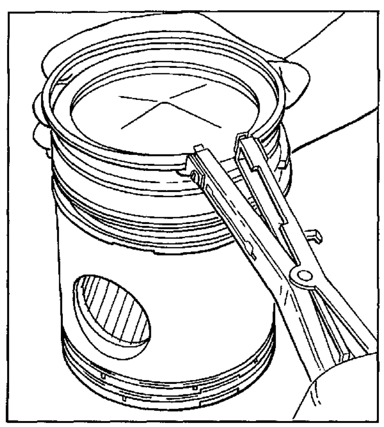


Figure 2. Removing or Installing Piston Ring using Tool J 8128

2. Punch a hole through the center of one of the piston pin retainers with a narrow chisel or punch and pry the retainer from the piston, being careful not to damage the piston or bushings.

3. Withdraw the piston pin from the piston, then remove the connecting rod.

4. Drive the remaining piston pin retainer out from the inside with a brass rod or other suitable tool.

Clean Piston

Clean the piston components with fuel oil and dry them with compressed air. If fuel oil does not remove the carbon deposits, use a chemical solvent (Fig. 3) that will not harm the piston pin bushings or the tinplate on the piston.

The upper part of the piston, including the compression ring lands and grooves, is not tin-plated and may be wirebrushed to remove any hard carbon. However, use care to avoid damage to the tin-plating on the piston skirt. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.

Clean the inside surfaces of the piston and the oil drain holes in the piston skirt. Exercise care to avoid enlarging the holes while cleaning them.

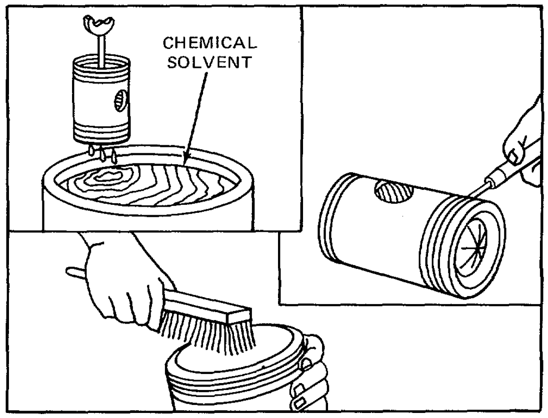


Figure 3. Cleaning Piston

Inspection

If the tinplate on the piston and the original grooves in the piston rings are intact, it is an indication of very little wear.

Excessively worn or scored pistons, rings, or cylinder liners may be an indication of abnormal maintenance or operating conditions, which should be corrected to avoid recurrence of the failure. The use of the correct types and proper maintenance of the lubricating oil filters and air cleaners will reduce, to a minimum, the amount of abrasive dust and foreign material introduced into the cylinders and will reduce the rate of wear.

Long periods of operation at idle speed and the use of improper lubricating oil or fuel must be avoided, otherwise a heavy formation of carbon may result and cause the rings to stick.

Keep the lubricating oil and engine coolant at the proper levels to prevent overheating of the engine.

Examine the piston for score marks, cracks, damaged ring-groove lands or indications of overheating. A piston with light score marks which may be cleaned up may be reused (Fig. 4). Any piston that has been severely scored or overheated must be replaced. Indications of overheating or burned spots on the piston may be the result of an obstruction in the connecting rod oil passage.

Replace the piston if cracks are found across the internal struts.

Check the cylinder liner and block bore for excessive out-of-round, taper, or high spots which could cause failure of the piston (refer to *Specifications).*

Inspection of the connecting rod and piston pin are covered in *Connecting Rod.*

Other factors that may contribute to piston failure include oil leakage into the air box, oil pullover from the air cleaner, dribbling injectors, combustion blow-by, and low oil pressure (dilution of the lubricating oil).

Inspect and measure the piston pin bush- ings. The piston pin-to-bushing clearance with new parts is 0.0025 to 0.0034 inch. A maximum clearance of 0.010 inch is allowable with worn parts. The piston pin bushings in the connecting rod are covered in *Connecting Rod.*

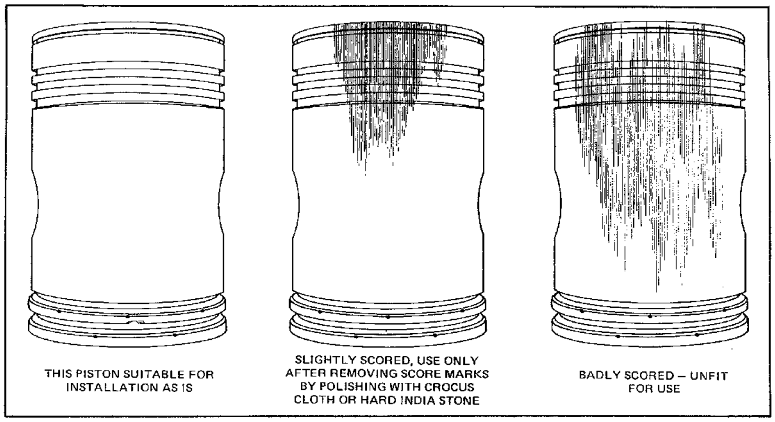


Figure 4. Comparison of Pistons Remove Bushings from Piston

Remove Bushing from Piston

1. Place the piston in holding fixture J 1513-1 so that the bushing bores are in alignment with the hole in the fixture base.

2. Drive each bushing from the piston with bushing remover J 4972-4 and handle J 1513-2 (Fig. 5).

Install Bushings in Piston

1. Place spacer J 7587-1 in the counterbore in fixture J 1513-1 (small end up).

2. Place the piston on the fixture so that the spacer protrudes into the bushing bore.

3. Insert installer J 4972-2 in a bushing, then position the bushing and installer over the lower bushing bore.

NOTE

Locate the joint in the bushing toward the bottom of the piston (Fig. 6).

4. Insert handle J 1513-2 in the bushing installer and drive the bushing in until it bottoms on the spacer.

5. Install the second bushing in the same manner.

6. The bushings must withstand an end load of 1800 pounds without moving after installation.

7. Ream the bushings to size as follows:

   a. Clamp reaming fixture J 5273 in a vise (Fig. 7). Then insert guide bushing J 4970-5 in the fixture and secure it with the setscrew.

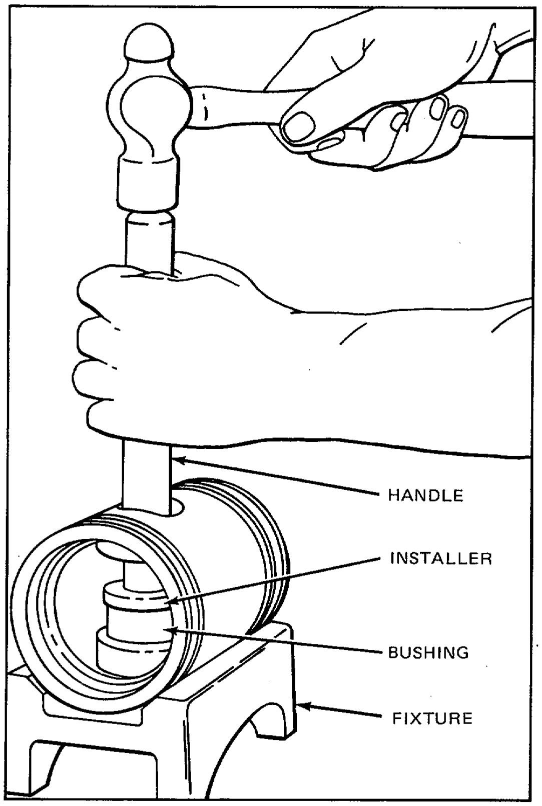


Figure 5. Removing or Installing Piston Pin Bushings

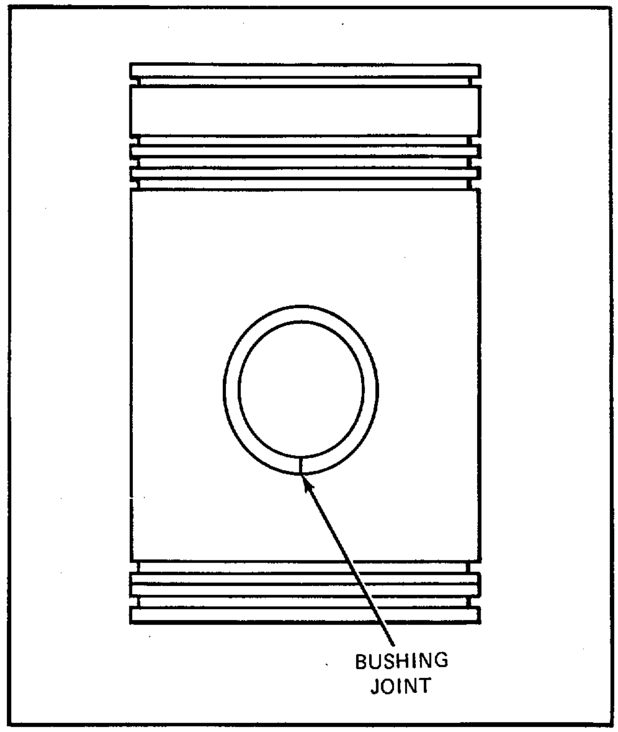


Figure 6. Location of Joint in Piston Pin Bushings

b. Place the piston in the fixture and insert the pilot end of reamer J 4970-4 through the clamping bar, bushings, and into the guide bushing.

c. With the piston, fixture, and reamer in alignment, tighten the wing- nuts securely.

d. Ream the bushings (Fig. 7). Turn the reamer in a clockwise direction only when reaming or withdrawing the reamer. For best results, use only moderate pressure on the reamer.

e. Withdraw the reamer and remove the piston from the fixture. Blow out the chips and measure the inside diameter of the bushings. The diameter must be 1.3775 to 1.3780 inches.

Fitting Piston

Measure the piston skirt diameter lengthwise and crosswise of the piston pin bore. Measurements should be taken at room temperature (70°F or 21°C). The taper and out-of-round must not exceed 0.0005 inches. Refer to *Specifications* for piston diameter specifications.

A new cylinder liner has an inside diameter of 3.8752 to 3.8767 inches. The piston-to-liner clearance, with new parts, is 0.0031 to 0.0068 inch (non-turbocharged engines) or 0.0061 to 0.0098 inch (turbocharged engines). A maximum clearance of 0.010 inch (non-turbocharged engines) or 0.012 inch (turbocharged engines) is allowable with used parts.

With the cylinder liner installed in the cylinder block, hold the piston upside down in the liner and check the clearance in four places, 900 apart (Fig. 8).

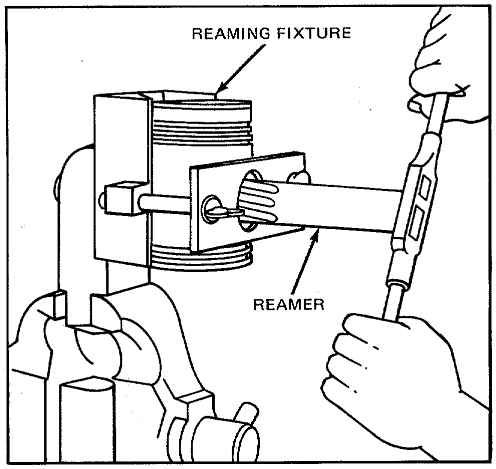


Figure 7. Reaming Piston Pin Bushings

Use feeler gage set J 5438-01 to check the clearance.

The spring scale, attached to the proper feeler gage, is used to measure the force in pounds required to withdraw the feeler gage.

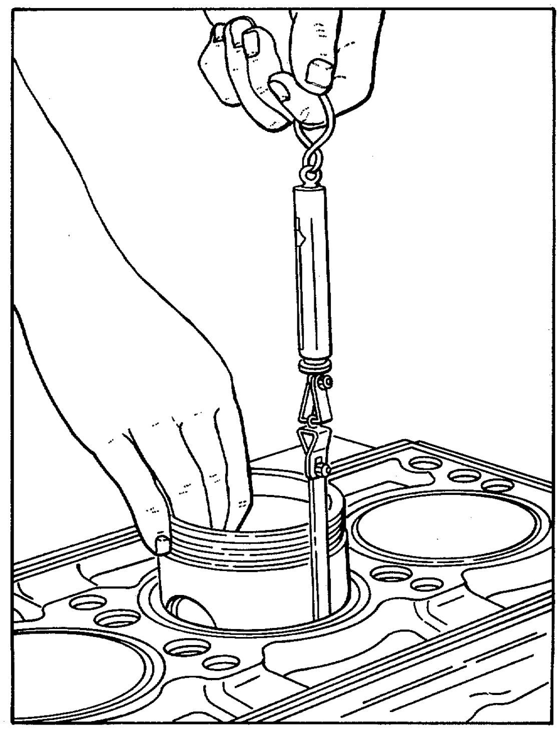


Figure 8. Measuring Piston-to-liner Clearance

Select a feeler gage with a thickness that will require a pull of 6 pounds to remove. The clearance will be 0.001 inch greater than the thickness of the feeler gage used, i.e., a 0.004 inch feeler gage will indicate a clearance of 0.005 inch when it is withdrawn with a pull of 6 pounds. The feeler gage must be perfectly flat and free of nicks and bends.

If any bind occurs between the piston and the liner, examine the piston and liner for burrs. Remove burrs with a fine hone (a flat one is preferable) and recheck the clearance.

Fitting Piston Rings

Each piston is fitted with a fire ring, three compression rings, and two oil control rings (Fig. 1).

The current top compression (fire) ring can be identified by the bright chrome on the bottom side and oxide (rust color) on the top. The former ring had a plain metal color on both sides.

A two-piece oil control ring is used in both oil ring grooves in the pistons for non-turbocharged (naturally aspirated) engines. A one-piece oil control ring is used in the upper ring groove and a two-piece ring in the lower ring groove in the pistons for turbocharged engines. Brazil-built engines use non-slotted upper oil control rings and low tension expanders.

All new piston rings must be installed whenever a piston is removed, regardless of whether a new or used piston or cylinder liner is installed.

Insert one ring at a time inside the cylinder liner and far enough down to be within the normal area of ring travel. Use a piston to push the ring down to be sure it is parallel with the top of the liner. Then measure the ring gap with a feeler gage as shown in Fig. 9. Refer to *Specifications* for ring gap.

If the gap on a compression ring is insufficient, it may be increased by filing or stoning the ends of the ring. File or stone both ends of the ring so the cutting action is from the outer surface to the inner surface. This will prevent any chipping or peeling of the chrome plate on the ring. The ends of the ring must remain square and the chamfer on the outer edge must be approximately 0.015 inch.

Check the ringside clearance as shown in Fig. 10. Ringside clearances are in *Specifications*.

Install Piston Rings

Before installing the piston rings, assemble the piston and rod as outlined under *Assemble Connecting Rod to Piston*. Then refer to Fig. 1 and install the piston rings.

CAUTION

Lubricate the piston rings and piston with engine oil before installing the rings.

COMPRESSION RINGS

1. Starting with the bottom ring, install the compression rings with tool J 8128 as shown in Fig. 2. To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston.

CAUTION

When installing the top compression (fire) ring with the tapered face, be sure the side marked TOP is toward the top of the piston.

2. Stagger the ring gaps around the piston.

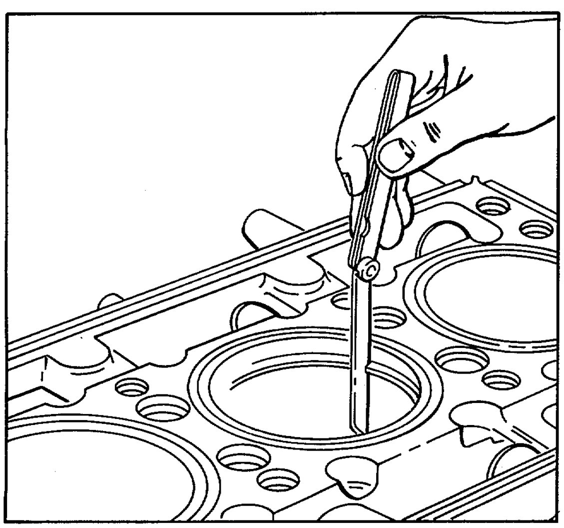


Figure 9. Measuring Piston Ring Gap

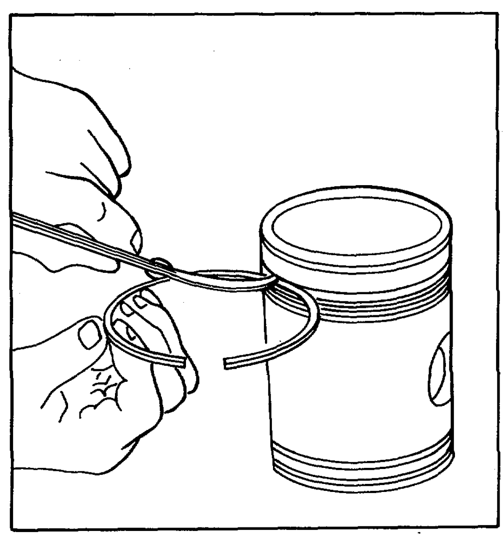


Figure 10. Measuring Piston Ringside Clearance

OIL CONTROL RINGS

Install the oil control rings as follows:

1. Install the ring expanders in the oil control ring grooves in the piston.

CAUTION

When installing the oil control rings, use care to prevent over- lapping the ends of the ring expanders. An overlapped ex- pander will cause the oil ring to protrude beyond allowable limits and will result in break- age when the piston is inserted in the ring compressor during installation in the cylinder liner. Do not cut or grind the ends of the expanders to prevent overlapping. Cutting or grinding the ends will decrease the expanding force on the oil control rings and result in high- lubricating oil consumption.

CAUTION

The scraper edges of all oil control rings must face downward (toward the bottom of the piston) for proper oil control.

2. Install the upper and lower halves of both oil control rings (naturally aspirated and turbocharged engines) as outlined above.

NOTE

If there is a noticeable resistance during installation of the piston, check for an overlapped ring expander.

CONNECTING ROD

Each connecting rod (Fig. 1 and 2) is forged to an I-section with a closed hub at the upper end and a bearing cap at the lower end. The connecting rod is drilled to provide lubrication to the piston pin at the upper end and is equipped with a nozzle to spray cooling oil to the underside of the piston head on engines equipped with an oil cooler. Engines that are not equipped with an oil cooler do not use nozzle-type connecting rods. An orifice is pressed into a counterbore at the lower end of the oil passage (in rods equipped with a spray nozzle) to meter the flow of oil.

CAUTION

> Never intermix nozzle-type connecting rods in an engine with non-nozzle-type connecting rods.

A helically-grooved bushing is pressed into each side of the connecting rod at the upper end. The cavity between the inner ends of these bushings registers with the drilled oil passage in the connecting rod and forms a duct around the piston pin. Oil entering this

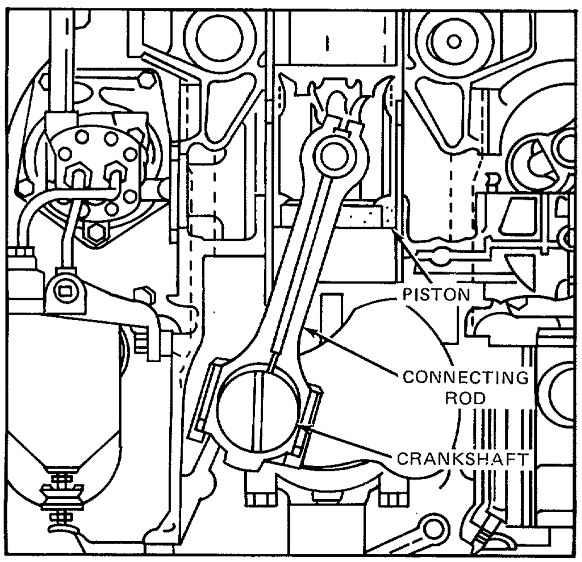


Figure 1. Connecting Rod Mounting

cavity lubricates the piston pin bushings and is then forced out the spray nozzle to cool the piston. The piston pin floats in the bushings of both the piston and the connecting rod.

The turbocharged engine connecting rods include vapor-blasted bushings and increased width oil grooves.

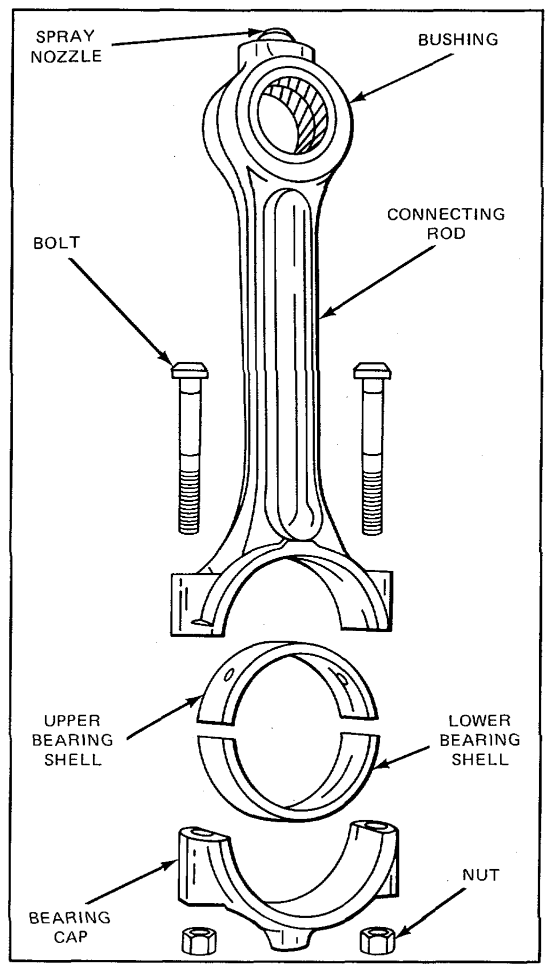


Figure 2. Connecting Rod Details and Relative Location of Parts

A service connecting rod includes the bearing cap, bolts, nuts, spray nozzle (if used), orifice, and the piston pin bushings pressed in place and bored to size.

Disassemble Connecting Rod from Piston

With the rod and piston assembly removed from the engine, disassemble the piston and connecting rod as outlined in *Piston and Piston Rings*.

Inspection

Clean the connecting rod and piston pin with fuel oil and dry them with compressed air. Blow compressed air through the drilled oil passage in the connecting rod to be sure the orifice, oil passage, and spray holes are not clogged.

Visually check the connecting rod for twisting or bending. Check for cracks (Fig. 3) by the magnetic particle method under *Crankshaft Inspection*.

If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap (refer to *Cylinder Liner*).

CAUTION

> Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure the orifice, oil passage, and spray holes are not clogged. Also make sure the split line (cap to rod) is thoroughly cleaned to avoid trapped contaminants from adversely affecting bearing shell crush.

Check the connecting rod bushings for indications of scoring, overheating, or other damage. Bushings that have overheated may become loose and creep together, thus blocking off the supply of lubricating oil to the piston pin, bushings, and spray nozzle.

Inspect the piston pin for signs of fretting. When reusing a piston pin, the highly polished and lapped surface of the pin must not in any way be refinished. Polishing or refinishing the piston pin is not recommended as it could result in very rapid bushing wear.

Since it is subjected to downward loading only, free movement of the piston pin is desired to secure perfect alignment and uniform wear. Therefore, the piston pin is assembled with a full-floating fit in the connecting rod and piston bushings, with relatively large clearances. Worn piston pin clearances up to 0.010 inch are satisfactory.

Remove Bushings

If it is necessary to replace the connecting rod bushings, remove them as follows:

1. Clamp the upper end of the connecting rod in holder J 7632 (Fig. 4) so that the bore in the bushings is aligned with the hole in the base of the holder.

2. Place bushing remover J 4972-4 in the connecting rod bushing, insert handle J 1513-2 in the remover, and drive the bushings from the rod.

Replace Spray Nozzle

The connecting rod bushings must be removed before the spray nozzle can be replaced. The orifice in the lower end of the drilled passage in the connecting rod is not serviced and it is not necessary to remove it when replacing the spray nozzle.

Replace the spray nozzle as follows:

1. Remove the connecting rod bushings.

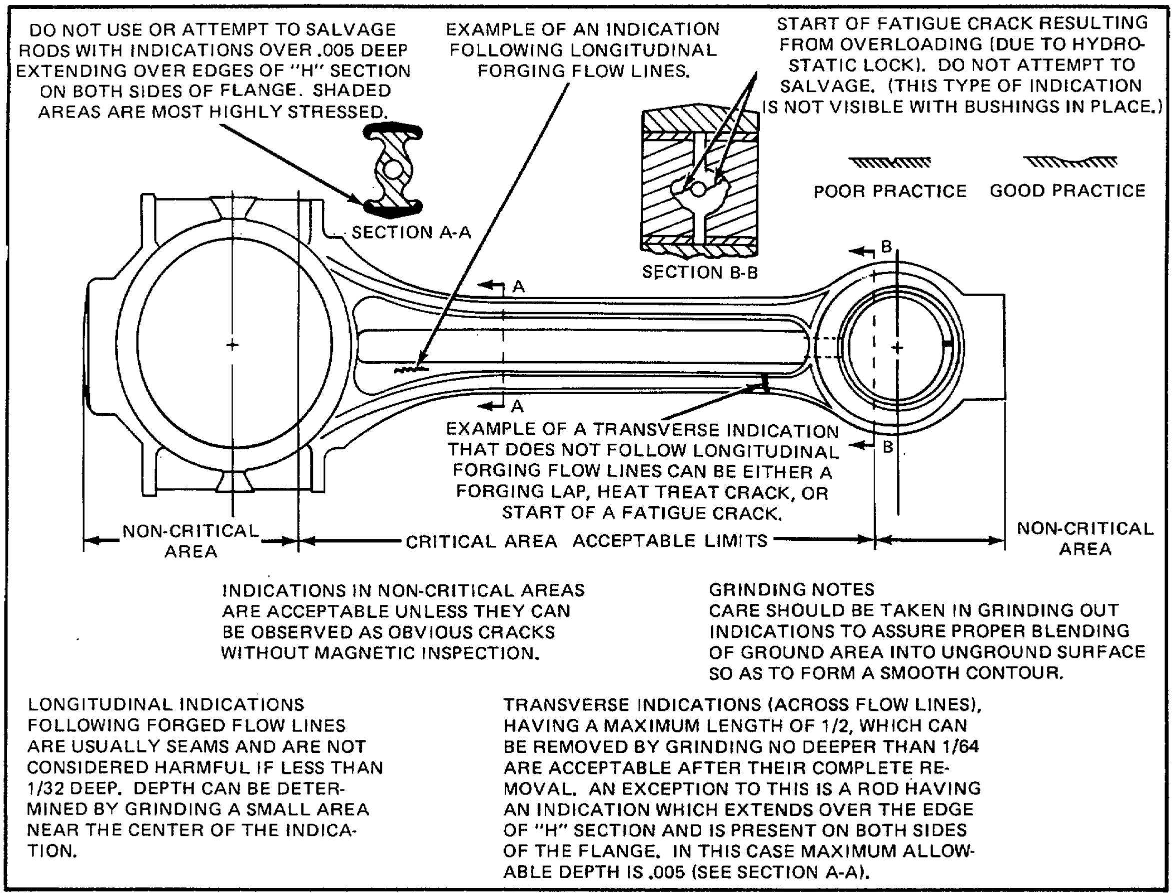


Figure 3. Magnetic Particle Inspection Limits for Connecting Rod

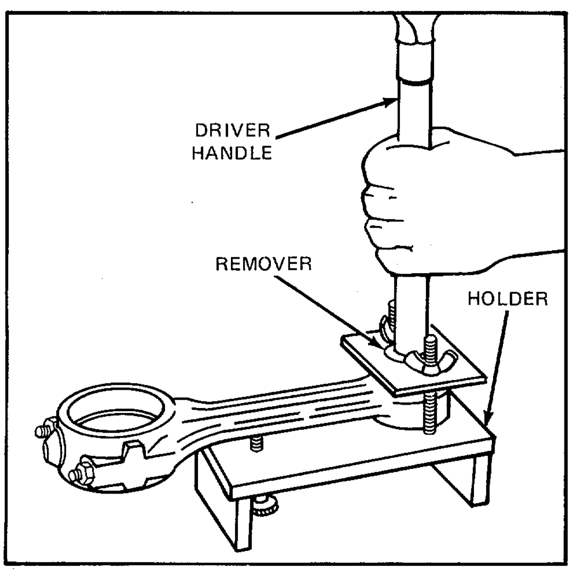


Figure 4. Removing or Installing Bushings

2. Insert spray nozzle remover J 8995 through the upper end of the connecting rod and insert the pin (in the curved side of the tool) in the opening in the bottom of the spray nozzle.

3. Support the connecting rod and tool in an arbor press as shown in Fig. 5.

4. Place a short sleeve directly over the spray nozzle. Then press the nozzle out of the connecting rod.

5. Remove the tool.

6. Start the new spray nozzle, with the holes positioned as shown in Fig. 6, straight into the counterbore in the connecting rod.

7. Support the connecting rod in the arbor press, place a short 3/8-inch I.D. sleeve on top of the nozzle and press the nozzle into the connecting rod until it bottoms in the counterbore.

8. Install new bushings in the connecting rod.

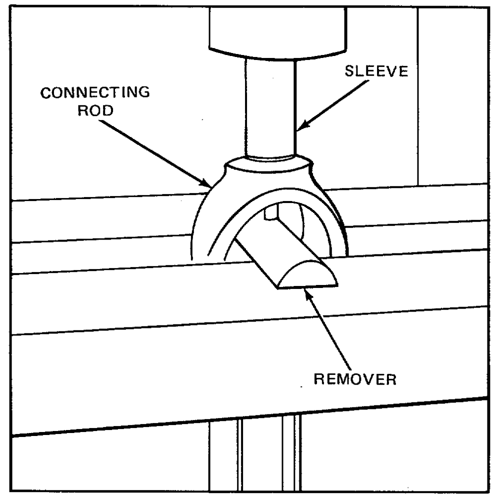


Figure 5. Removing Spray Nozzle

Install Bushings

1. Clamp the upper end of the connecting rod assembly in holder J 7632 so that the bore for the bushings aligns with the hole in the base of the tool (Fig. 4).

2. Start a new bushing straight into the bore of the connecting rod, with the bushing joint at the top of the rod (Fig. 7).

3. Insert installer J 4972-2 in the bushing, then insert handle J 1513-2 in the installer and drive the bushing in until the flange of the installer bottoms on the connecting rod.

4. Turn the connecting rod over in the holder and install the second bushing in the same manner.

5. The bushings must withstand an end load of 2000 pounds without moving after installation.

6. Ream the bushings to size as follows:

   a. Clamp reaming fixture J 7608-4 in a bench vise.

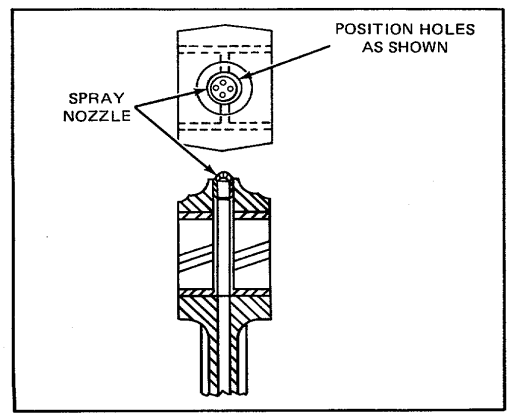


Figure 6. Position of Spray Nozzle Holes

   b. Place the crankshaft end of the connecting rod on the arbor of the fixture (Fig. 8). Tighten the nuts on the 3/8-24 bolts to 40-45 lb ft (54-61 Nm) torque.

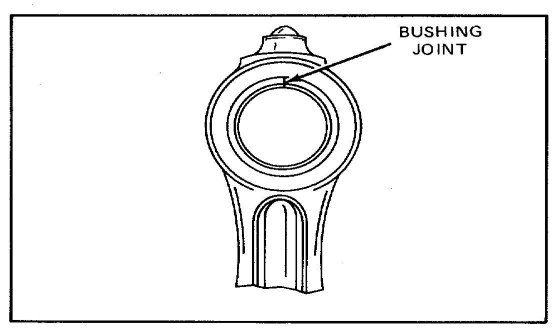


Figure 7. Location of Bushing Joint

c. Slide the front guide bushing J 4971-6 (with the pin end facing out) in the fixture.

d. Install spacer J 7608-3 in the fixture.

e. Align the upper end of the connecting rod with the hole in the reaming fixture.

f. Install the rear guide bushing J 1686-5 on the reamer J 7608-21, then slide the reamer and bushing into the fixture.

g. Turn the reamer in a clockwise direction only when reaming or with- drawing the reamer. For best results, use only moderate pressure on the reamer.

h. Remove the reamer and the connecting rod from the fixture, blow out the chips, and measure the inside diameter of the bushings. The inside diameter of the bushings must be 1.3760 to 1.3765 inches. This will provide a piston pin-to-bushing clearance of 0.0010 to 0.0019 inch with a new piston pin. A new piston pin has a diameter of 1.3746 to 1.3750 inches.

Assemble Connecting Rod to Piston

Apply clean engine oil to the piston pin and bushings. Refer to Fig. 2 and assemble the connecting rod to the piston as follows:

1. Place the piston in the holding fixture (Fig. 9).

2. Place a new piston pin retainer in position. Then place the crowned end of installer J 23762 against the retainer and strike the tool just hard enough to deflect the retainer and seat it evenly in the piston.

CAUTION

Do not drive the retainer in too far or the piston bushing may be moved inward and result in reduced piston pin end clearance.

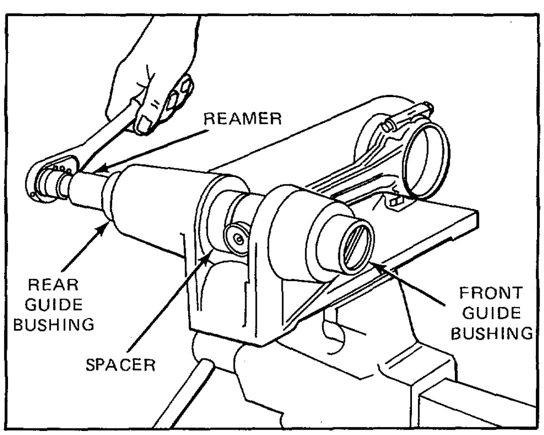


Figure 8. Reaming Bushings

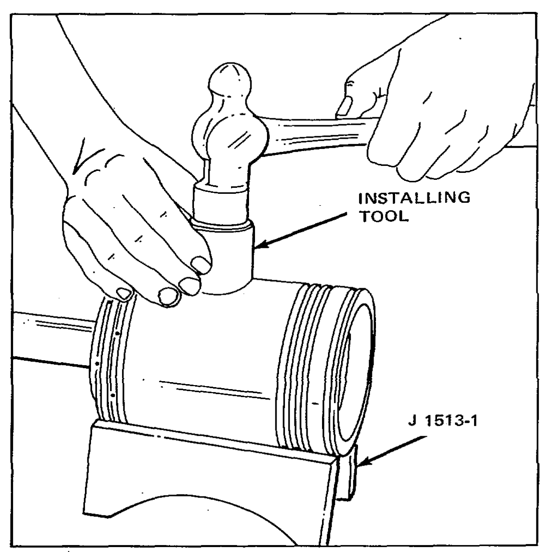


Figure 9. Installing Piston Pin Retainer

CONNECTING ROD

3. Place the upper end of the connecting rod between the piston pin bosses and in line with the piston pin holes. Then slide the piston pin in place. If the piston pin-to-bushing clearances are within the specified limits, the pin will slip into place without use of force.

4. Install the second piston pin retainer as outlined in steps 1 and 2.

5. After the piston pin retainers have been installed, check for piston pin end clearance by cocking the connecting rod and shifting the pin in its bushings.

6. One important function of the piston pin retainer is to prevent the oil, which cools the underside of the piston and lubricates the piston pin bushings, from reaching the cylinder walls. Check each retainer for proper sealing with leak detector J 23987 (Fig. 10). Place the suction cup over the retainer and hand operate the lever to pull a vacuum of 10 inches on the gage. A drop in the gage reading indicates air leakage at the retainer.

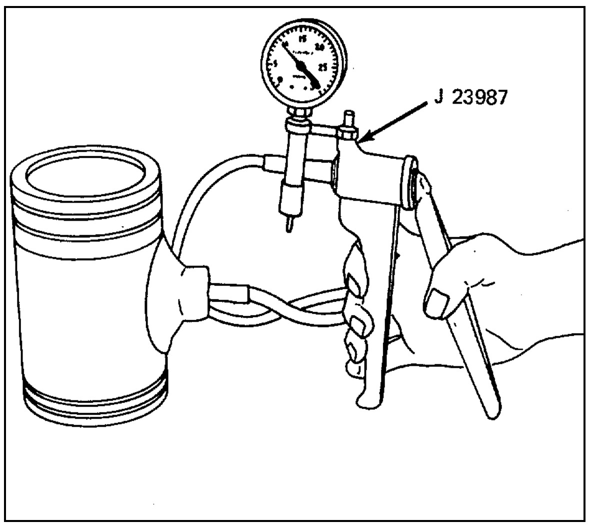


Figure 10. Checking Piston Pin Retainer for Proper Sealing

7. Install the piston rings on the piston as outlined in *Piston and Piston Rings*.

8. Install the piston and connecting rod assembly in the engine as outlined in Cylinder Liner.

CONNECTING ROD BEARINGS

The connecting rod bearing shells (Fig. 1) are precision made and are replaceable without shim adjustments. They consist of an upper bearing shell seated in the connecting rod and a lower bearing shell seated in the connecting rod cap. The bearing shells are prevented from endwise or radial movement by a tang at the parting line at one end of each bearing shell.

The upper and lower connecting rod bearing shells are different and are not interchangeable. The upper bearing shell has two, short oil grooves and two oil holes; each groove begins at the end of the bearing shell and terminates at an oil hole. The lower bearing shell has a continuous oil groove from one end of the shell to the other. These grooves maintain a continuous registry with the oil hole in the crankshaft connecting rod journal, thereby providing a constant supply of lubricating oil to the connecting rod bearings, piston pin bushings, and spray nozzle through the oil passage in the connecting rod.

The Brazilian-built engine, connecting rod bearings include a slotted upper shell.

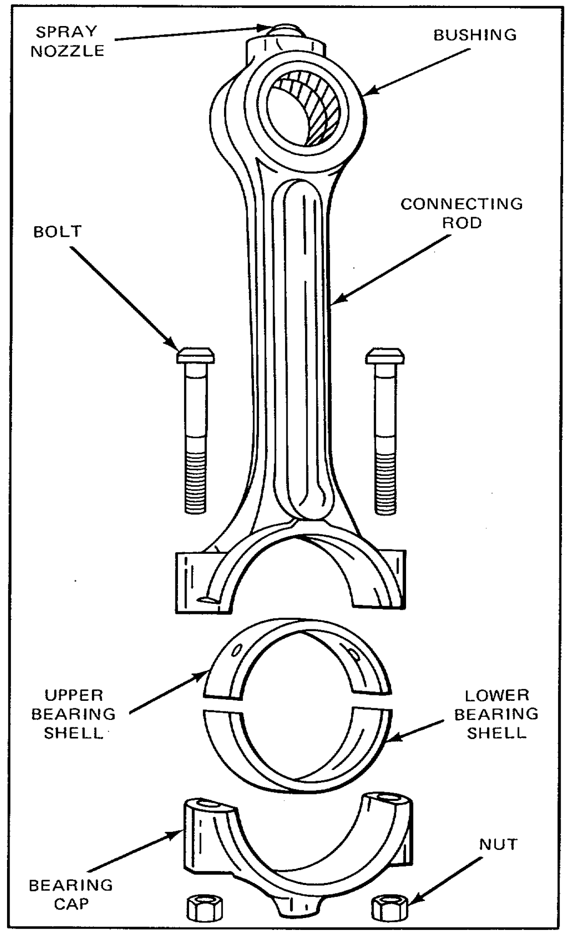


Figure 1. Connecting Rod and Bearing Shells

Remove Bearing Shells

The connecting rod bearing caps are numbered 1, 2, 3, etc. on an in-line engine with matching numbers stamped on the connecting rods. When removed, each bearing cap and the bearing shells must always be reinstalled on the original connecting rod.

Remove the connecting rod bearings as follows:

1. Drain the oil and remove the oil pan.

2. Remove the oil inlet pipe and screen assembly.

3. Remove one connecting rod bearing cap. Push the connecting rod and piston assembly up into the cylinder liner far enough to permit removal of the upper bearing shell. Do not pound on the edge of the bearing shell with a sharp tool.

4. Inspect the upper and lower bearing shells as outlined under *Inspection.*

CONNECTING ROD BEARINGS

5. Install the bearing shells and bearing cap before another connecting rod bearing cap is removed.

Inspection

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present which cause acid etching, flaking, and pitting. Bearing seizure may be due to low oil or no oil.

After removal, clean the bearings and inspect them for scoring, pitting, flaking, etching, or signs of over-heating. If any of these defects are present, the bearings must be discarded. The upper bearing shells, which carry the load, will normally show signs of distress before the lower bearing shells do.

Inspect the backs of the bearing shells for bright spots, which indicate they have been shifting in their supports. If such spots are present, discard the bearing shells. Also inspect the connecting rod bearing bore for burrs, foreign particles, etc.

Measure the thickness of the bearing shells, using a micrometer and ball attachment J 4757, as described under *Inspection*. The minimum thickness of a worn, standard connecting rod bearing shell should not be less than 0.1230 inch and, if either bearing shell is thinner than this dimension, replace both bearing shells. A new standard bearing shell has a thickness of 0.1245 to 0.1250 inch (in-line engine). Refer to Table 1.

In addition to the thickness measurement, check the clearance between the connecting rod bearing shells and the crankshaft journal. This clearance may be checked by means of a soft plastic

Table 1

Bearing Size	Minimum *New Bearing Thickness	Worn Thickness
In-Line Engines		
Standard	0.1245 - 0.1250 inch	0.1230 inch
0.002 inch Undersize	0.1255 - 0.1260 inch	0.1240 inch
0.010 inch Undersize	0.1295 - 0.1300 inch	0.1280 inch
0.020 inch Undersize	0.1345 - 0.1350 inch	0.1330 inch
0.030 inch Undersize	0.1395 - 0.1400 inch	0.1380 inch

*Thickness 90° from parting line of bearing.

measuring strip which is squeezed between the journal and the bearing (refer to *Shop Notes*). The maximum connecting rod bearing-to-journal clearance with used parts is 0.006 inch.

Before installing the bearings, inspect the crankshaft journals (refer to *Inspection*).

Do not replace one connecting rod bear-ing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells. Bearing shells are available in 0.010, 0.020, and 0.030 inch undersize for service with reground crankshafts. To determine the size bearings required, refer to *Crankshaft Grinding*. Bearings which are 0.002 inch undersize are available to compensate for slight journal wear where it is unnecessary to regrind the crankshaft.

CAUTION

Bearing shells are NOT rework- able from one undersize to another under any circumstances.

Install Connecting Rod Bearing Shells

With the crankshaft and the piston and connecting rod assembly in place, in- stall the connecting rod bearings as follows:

1. Rotate the crankshaft until the connecting rod journal is at the bottom of its travel, then wipe the journal clean and lubricate it with clean engine oil.

2. Install the upper bearing shell (the one with the short groove and oil hole at each parting line) in the connecting rod. Be sure the tang on the bearing shell fits in the groove in the connecting rod.

3. Pull the piston and rod assembly down until the upper rod bearing seats firmly on the crankshaft journal.

4. Note the numbers stamped on the connecting rod and the bearing cap and install the lower bearing shell (the one with the continuous oil groove) in the bearing cap, with the tang on the bearing shell in the groove in the bearing cap.

5. Install the bearing and cap and tighten the nuts on the 3/8-24 bolts to 40-45 lb ft (54-61 Nm) torque.

CAUTION

Be sure the connecting rod bolt has not turned in the connecting rod before the torque is applied to the nut.

6. Install the lubricating oil pump inlet tube assembly. Replace the inlet tube seal ring or elbow gasket if hardened or broken.

7. Install the oil pan using a new gasket.

8. Refer to the *Lubricating Oil Specifications* and fill the crankcase to the proper level on the dipstick.

9. If new bearings were installed, operate the engine on the run-in schedule as outlined in *Run-In Instructions.*

CYLINDER LINER

The cylinder liner (Fig. 1) is of the replaceable wet type, made of hardened alloy cast iron, and is a slip fit in the cylinder block. The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner rests on a counterbore in the top of the block.

A synthetic rubber seal ring, recessed in the cylinder block bore, is used between the liner and the block to prevent water leakage into the air box.

The upper portion of the liner is directly cooled by water surrounding the liner. The center portion of the liner is air cooled by the scavenging air which enters the cylinder through equally spaced ports. However, regardless of the type of cooling, the current cylinder liner is applicable to all engines.

The air inlet ports in the liner are machined at an angle to create a uniform swirling motion to the air as it enters the cylinder. This motion persists throughout the compression stroke and facilitates scavenging and combust ion.

The wear on a liner and piston is directly related to the amount of abrasive dust and dirt introduced into the engine combustion chamber through the air intake. This dust, combined with lubricating oil on the cylinder wall, forms a lapping compound and will result in rapid wear. Therefore, to avoid pulling contaminated air into the cylinder, the air cleaners must be serviced regularly according to the surroundings in which the engine is operating.

Remove Cylinder Liner

It is very important that the proper method is followed when removing a cylinder liner. DO NOT attempt to push the liner out by inserting a bar in the liner ports and rotating the crankshaft, otherwise the piston may be damaged or the upper ring groove may collapse.

To remove a cylinder liner, refer to Fig. 2 and proceed as follows:

1. Remove the piston and connecting rod assembly as outlined in *Piston and Piston Rings.*

2. Remove the cylinder liner with tool set J 22490 as follows:

    a. Slip the lower puller clamp up on the puller rod and off the tapered seat. Cock the clamp so it will slide down through the liner. The clamp will drop back on the tapered seat after it clears the bottom of the liner. Then slide the upper puller clamp down against the top edge of the liner.

    b. With the tool in place, strike a sharp blow on the upset head on the

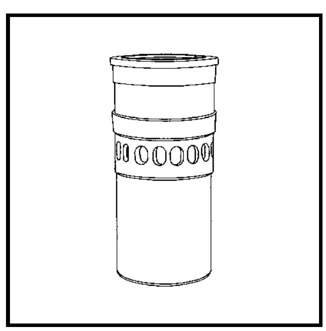


Figure 1. Cylinder Liner

upper end of the puller rod with the puller weight, thus releasing the liner.

c. Remove the tool from the liner. Then remove the liner from the cylinder block.

d. Remove and discard the cylinder liner seal ring from the groove in the cylinder block bore.

If tool J 22490 is unavailable, tap the liner out with a hardwood block and hammer.

Inspect Cylinder Liner

When the cylinder liner is removed from the cylinder block, it must be thoroughly cleaned and then checked for the following:

1. Cracks
2. Scoring
3. Poor contact on outer surface
4. Flange irregularities
5. Inside diameter
6. Outside diameter
7. Out-of-round
8. Taper

A cracked or excessively scored liner must be discarded. A slightly scored liner may be cleaned up and reused.

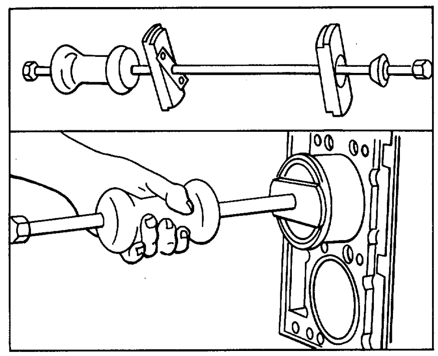


Figure 2. Removing Cylinder Liner with Tool J 22490

Excessive liner-to-block clearance or block bore distortion will reduce heat transfer from the liner to the block and to the engine coolant.

Examine the outside diameter of the liner for fretting below the ports. Fretting is the result of a slight movement of the liner in the block bore during engine operation, which causes material from the block to adhere to the liner. These metal particles may be removed from the surface of the liner with a coarse, flat stone.

Measure the block bore (*Cylinder Block*) and the outside diameter of the liner (refer to *Specifications*).

A used cylinder liner must be honed for the following reasons:

NOTE

Do not modify the surface finish in a new service cylinder liner. Since the liner is properly finished at the factory, any change will adversely affect seating of the piston rings.

1. To break the glaze (Fig. 3) due to the rubbing action of the piston rings after long periods of operation. (Unless this glaze is removed, the time required to seat new piston rings will be lengthened.)

2. To remove the ridge (Fig. 4) formed at the top by the piston ring travel. (Otherwise, interference with the travel of the new compression rings may result in ring breakage.)

Therefore, even though the taper and out-of-round are within the specified limits, the glaze and ridge must be removed by working a hone up and down the full length of the liner a few times.

Place the liner in a fixture (a scrap cylinder block makes an excellent honing fixture). However, if it is necessary to hone a liner in the cylinder block that is to be used in building up the engine, the engine must be dismantled and then, after honing, the cylinder block and other parts must be thoroughly cleaned to ensure that all abrasive material is removed.

The hone J 5902-01, equipped with 120-grit stones J 5902-14, should be worked up and down (at 300-400 rpm) the full length of the liner a few times in a criss-cross pattern that produces hone marks on a 45° axis.

After the liner has been honed, remove it from the fixture and clean it thoroughly. Then dry it with compressed air and check the entire surface for burrs.

After honing, the liner must conform to the same limits on taper and out-of- round as a new liner, and the piston- to-liner clearance must be within the specified limits (*Specifications*).

Install the liner (new or used) in the proper bore of the cylinder block and measure the inside diameter at the various points shown in Fig. 5. Use cylinder bore gage J 5347-01 (Fig. 6), which has a dial indicator calibrated in 0.0001-inch increments. Set the cylinder bore gage on zero in master ring gage J 8385-01. Also check the liner for taper and out-of-round.

NOTE

Dial bore gage, master setting fixture J 23059-01 may be used in place of the master ring gage.

The piston-liner clearance must be within the specified limits. Also, the taper must not exceed 0.002 inch and the out-of-round must not exceed 0.003 inch on a used liner. The taper must not exceed 0.001 inch and the out-of- round must not exceed 0.002 inch on a new liner.

New service liners have an inside diameter of 3.8752 to 3.8767 inches.

Fitting Cylinder Liner in Block Bore

1. Wipe the inside and outside of the liner clean and make sure the block bore and counterbore are clean.

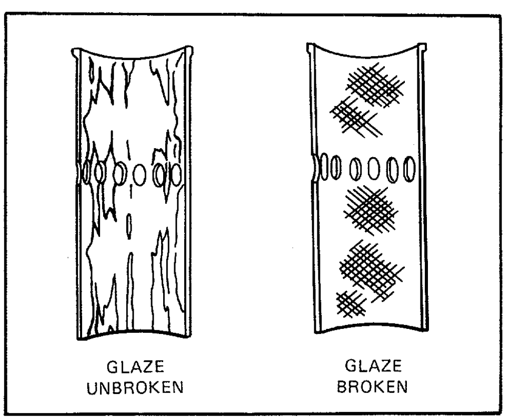


Figure 3. Glazed Surface of Cylinder Liner

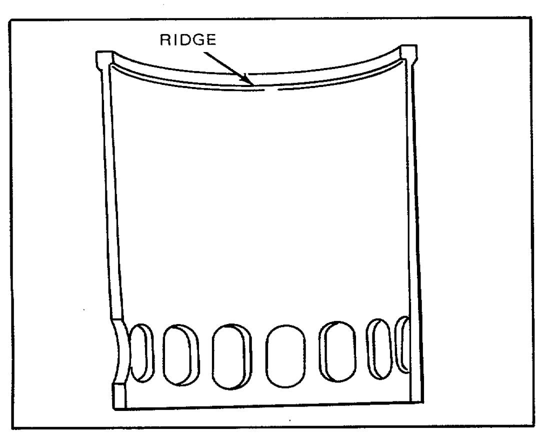


Figure 4. Cylinder Liner Ridge Due to Wear

2. Slide the liner into the block until the flange rests on the bottom of the counterbore in the block.

CAUTION

Do not drop or slam the liner flange against the bottom of the counterbore in the block.

3. Tap the liner lightly with a soft hammer to make certain the liner flange seats on the bottom of the counterbore.

4. Install a cylinder liner holddown clamp as illustrated in Fig. 7.

5. Measure the distance from the top of the liner flange to the top of the block with a dial indicator (Fig. 7). The liner flange must be 0.0465 to 0.0500 inch below the top of the block. However, even though all of the liners are within these specifications, there must not be over 0.002 inch difference between any two adjacent liners when measured along the cylinder longitudinal center line. If the above limits are not met, install the liner in another bore and recheck, or use a new liner.

6. Matchmark the liner and the cylinder block with a felt pen so the liner may be reinstalled in the same position in the same block bore. Place the matchmarks on the engine serial number side of the block (in-line engine).

7. Remove the holddown clamp and the cylinder liner.

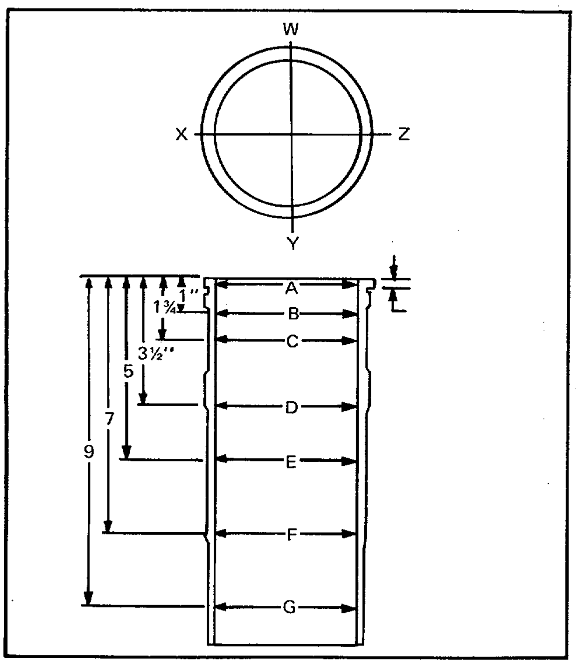


Figure 5. Cylinder Liner Measurement Diagram

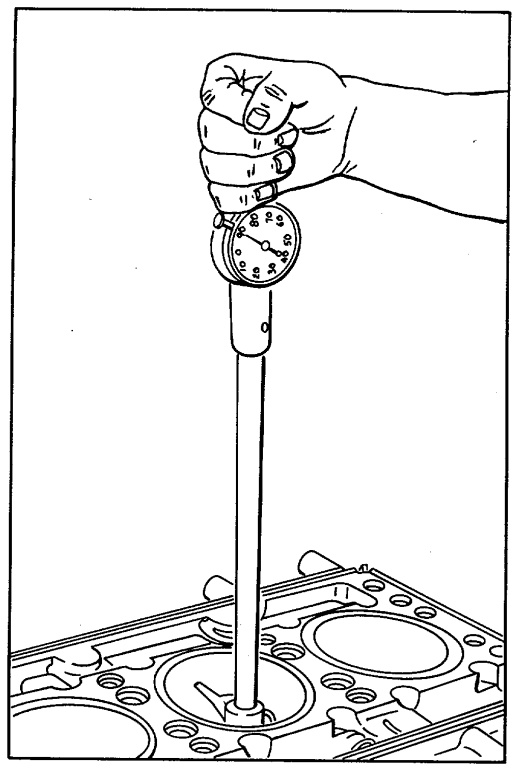


Figure 6. Checking Bore of Cylinder Liner using Tool J 5347-01

Install Piston and Connecting Rod Assembly

1. With the piston assembled to the connecting rod and the piston rings in place, apply clean engine oil to the piston, rings, and inside surface of piston ring compressor J 6883-01.

CAUTION

Inspect the ring compressor for nicks or burrs, especially at the non-tapered inside diameter end. Nicks or burrs on the inside diameter of the compressor will result in damage to the piston rings.

2. Place the piston ring compressor on a woodblock, with the tapered end of the ring compressor facing up.

3. Position (stagger) the piston ring gaps properly on the piston. Make sure the ends of the oil control ring expanders are not overlapped.

4. Start the top of the piston straight into the ring compressor. Then push the piston down until it contacts the woodblock (Operation 1 of Fig. 8).

5. Note the position of the match- mark and place the liner, with the flange end down, on the woodblock.

6. Place the ring compressor and the piston and connecting rod assembly on the liner so the numbers on the rod and cap are aligned with the matchmark on the liner (Operation 2 of Fig. 8).

CAUTION

The numbers, or number and letter, on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers, or number and letter, must be stamped in the same location as on the connecting rod that was replaced.

7. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.

CAUTION

Do not force the piston into the liner. The peripheral, abutment-type expanders apply considerably more force on the oil ring than the standard expander. Therefore, extra care must be taken during the loading operation to prevent ring breakage.

8. Remove the connecting rod cap and the ring compressor. Then push the piston down until the compression rings pass the cylinder liner ports.

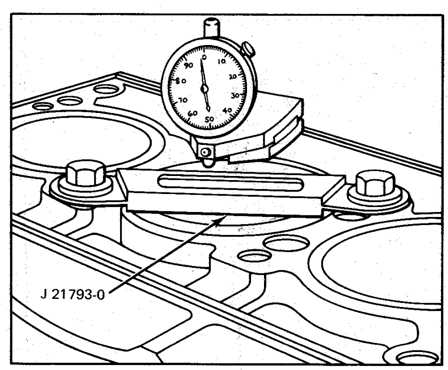


Figure 7. Checking Distance of Liner Flange Below Top Face of Block Using J 22273-01 and Holddown Tool J 21793-B

Install Cylinder Liner, Piston, and Connecting Rod Assembly

After the piston and connecting rod assembly have been installed in the cylinder liner, install the entire assembly in the engine as follows:

1. Make sure the seal ring grooves in the cylinder block bore are clean. Then install a new seal ring(s).

NOTE

The current cylinder block has an additional seal ring groove approximately 1/8 inch below the original top groove (Fig. 9). This groove will permit further use of the cylinder block where corrosion or erosion of the upper seal ring groove has occurred. The lower seal ring groove in the current cylinder block has been eliminated. Reinstallation of the lower seal ring is not necessary in the former cylinder block.

2. Apply hydrogenated, vegetable- type shortening or permanent-type antifreeze to the inner surface of the seal ring.

3. If any of the pistons and liners are already in the engine, use holddown clamps to retain the liners in place when the crankshaft is rotated.

4. Rotate the crankshaft until the connecting rod journal of the particular cylinder being worked on is at the bottom of its travel. Wipe the journal clean and lubricate it with clean engine oil.

5. Install the upper bearing shell (the one with a short oil groove at each parting line) in the connecting rod. Lubricate the bearing shell with clean engine oil.

6. Position the piston, rod, and liner assembly in line with the block bore (Fig. 10) so that the identification number on the rod is facing the engine serial number side (in-line engine). Also align the matchmarks on the liner and the block. Then slide the entire assembly into the block bore and seal ring, being careful not to damage the seal ring.

7. Push or pull the piston and connecting rod into the liner until the upper bearing shell is firmly seated on the crankshaft journal.

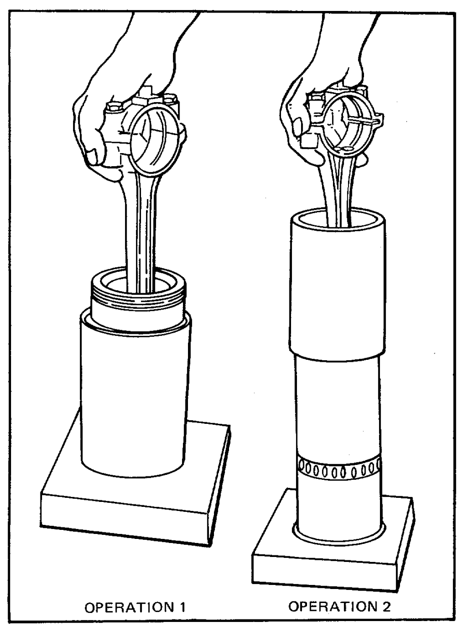


Figure 8. Installing Piston and Connecting Rod Assembly in Ring Compressor and Cylinder Liner

8. Place the lower bearing shell (the one with the continuous oil groove from one parting line to the other) in the connecting rod cap, with the tang on the bearing shell in the notch in the connecting rod bearing cap. Lubricate the bearing shell with clean engine oil.

9. Install the bearing cap and the bearing shell on the connecting rod with the identification numbers on the cap and the rod adjacent to each other. On the 3/8-24 bolts, tighten the nuts to 40-45 lb ft (54-61 Nm) torque.

IMPORTANT

Be sure the connecting rod bolt has not turned in the connecting rod before the torque is applied to the nut.

10. Check the connecting rod side clearance. The clearance between the side of the rod and the crankshaft should be 0.006 to 0.012 inch with new parts on an in-line engine.

11. Install the remaining liner, piston, and rod assemblies in the same manner. Use holddown clamps to hold each liner in place.

12. After all of the liners and pistons have been installed, remove the holddown clamps.

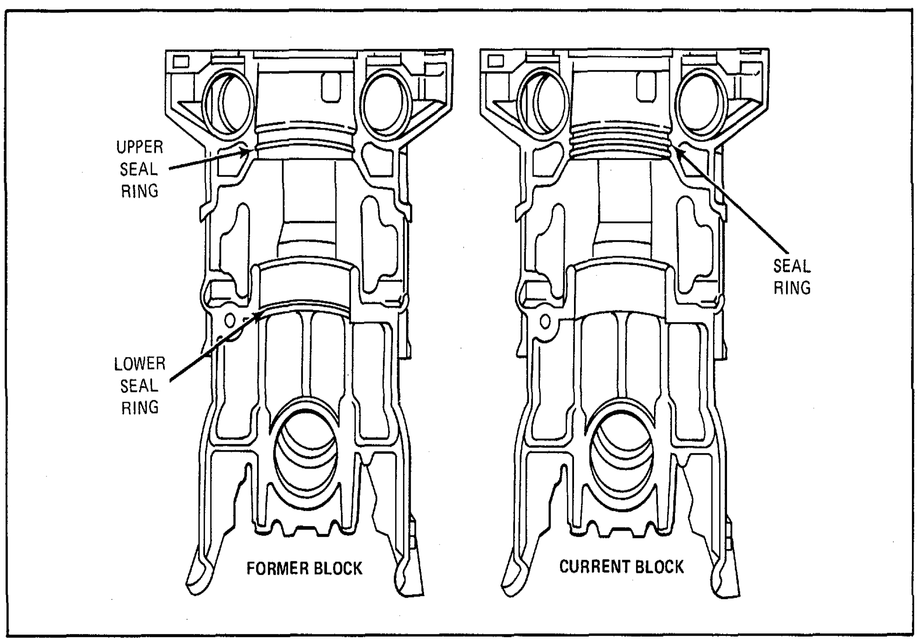


Figure 10. Installing Piston, Rod, and Liner Assembly in Cylinder Block

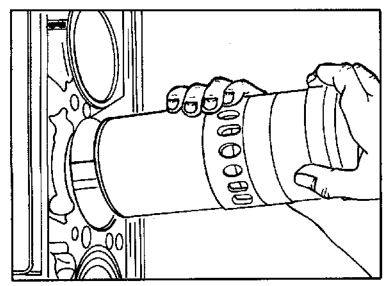


Figure 9. Cylinder Liner Seal Ring Location in Cylinder Block Bore

13. Install new compression gaskets and water and oil seals as outlined in Cylinder Head. Then install the cylinder head and any other parts that were removed from the engine.

14. After the engine has been completely reassembled, refer to the Lubricating Oil Specifications and refill the crankcase to the proper level on the dipstick.

15. Close all the drains and fill the cooling system.

16. If new parts such as pistons, rings, cylinder liners, or bearings were installed, operate the engine on the Run-in schedule.

ENGINE BALANCE AND BALANCE WEIGHTS

In the balance of two-cycle engines, it is important to consider disturbances due to the reciprocating action of the piston masses. These disturbances are of two kinds: unbalanced forces and unbalanced couples. These forces and couples are considered as primary or secondary according to whether their frequency is equal to engine speed or twice engine speed. Although it is possible to have unbalanced forces or couples at frequencies higher than the second order, they are of small consequence in comparison to the primary forces and couples. Even the secondary forces and couples are usually of little practical significance.

The reciprocating masses (the piston and upper end of the rod) produce an unbalanced couple due to their arrangement on the crankshaft. On an in-line engine, this unbalanced couple tends to rock the engine from end to end in a vertical plane. This couple is cancelled by incorporating an integral crankshaft balance component and by placing balance weights at the outer ends of the balance shaft and camshaft. This balance arrangement produces a couple that is equal and opposite in magnitude and direction to the primary couple.

On the balance shaft and camshaft (in-line engine), each set of weights (weights on the outer ends of each shaft comprise a set) rotates in an opposite direction with respect to the other. When the weights on either end of the engine are in a vertical plane, their centrifugal forces are in the same direction and oppose the primary couple. When they are in a horizontal plane, the centrifugal forces of these balance weights oppose each other and are, therefore, canceled. The front balance weights act in a direction opposite to the rear balance weights; therefore, rotation will result in a couple effective only in a vertical plane. This couple, along with that built into the crankshaft, forms an elliptical couple which completely balances the primary couple.

The balance weights are integral with the gears and the circular balance weights (pulleys) on the shafts. Additional weights are attached to the camshaft and balance shaft. gears.

Both the rotating and primary reciprocating forces and couples are completely balanced in the engines. Consequently, the engines will operate smoothly and in balance throughout their entire speed range.

Remove Front Balance Weights

1. Remove the nut at each end of both shafts as outlined in *Camshaft and Bearings*.

2. Force the balance weight off the end of each shaft, using two screw-drivers or pry bars between the balance weight and the upper front cover as shown in Fig. 1.

Install Front Balance Weights

1. Reinstall the Woodruff keys in the shafts, if they were removed.

2. Align the keyway in the balance weight with the key in the shaft, then slide the weight on the shaft. If the weight does not slide easily onto the shaft, loosen the thrust washer retaining bolts at the opposite end of the shaft. Then, to prevent possible damage to the thrust washer, support the rear end of the shaft while tapping the weight into place with a hammer and a sleeve. Retighten the thrust washer retaining bolts to 30-35 lb ft (41-47 Nm) torque. Install the other weight in the same manner.

3. Wedge a clean rag between the gears. Refer to Fig. 1 *Camshaft and Bearings* and tighten the gear retaining nuts to 300-325 lb ft (407-441 Nm) torque. Then tighten the front balance weight retaining nuts to 300-325 lb ft (407-441 Nm) torque. Remove the rag from the gears.

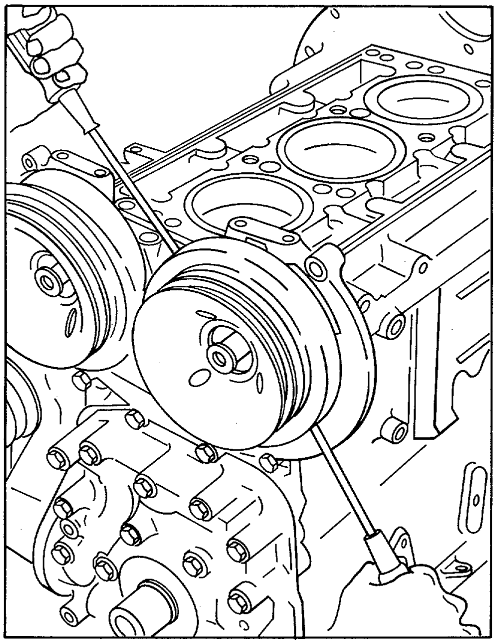


Figure 1. Removing Front Balance Weight (Pulley Type)

GEAR TRAIN AND ENGINE TIMING

A train of helical gears, completely enclosed between the engine end plate and the flywheel housing, is located at the rear of the Series 53 engine.

The gear train on an in-line engine (Fig. 1) consists of a crankshaft gear, an idler gear, a camshaft gear, and a balance shaft gear. The governor drive gear and the blower drive gear for the four-cylinder engine are driven by the camshaft gear or balance shaft gear, depending upon the engine model.

On in-line engines, the crankshaft gear is pressed on and keyed to the end of the crankshaft.

The idler gear rotates on a stationary hub.

The camshaft and balance shaft gears on in-line engines are pressed on and keyed to their respective shafts and each gear is secured by a retaining nut and lock plate.

The camshaft and balance shaft gears on an in-line engine mesh with each other and run at the same speed as the crank-shaft gear. Since the camshaft gears must be in time with each other, and the two as a unit in time with the crankshaft gear, timing marks have been stamped on the face of the gears to facilitate correct gear train timing.

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, it is important to remember the engine rotation. Then, working from the crankshaft gear to the idler gear and to the camshaft and/or balance shaft gear in that order, line up the appropriate circle symbols on the gears or the appropriate triangles as each gear assembly is installed on the engine. Refer to Fig. 1.

CAUTION

> It is advisable to make a sketch indicating the position of the timing marks BEFORE removing or replacing any of the gears in the gear train.

The circle and the triangle are the basic timing symbols stamped on the gears. The letters stamped on the crankshaft gears identify the proper timing marks for the particular engine: I represents in-line engine, V represents V-type engine, R represents right-hand rotation engine, L represents left-hand rotation engine, and A represents advanced timing.

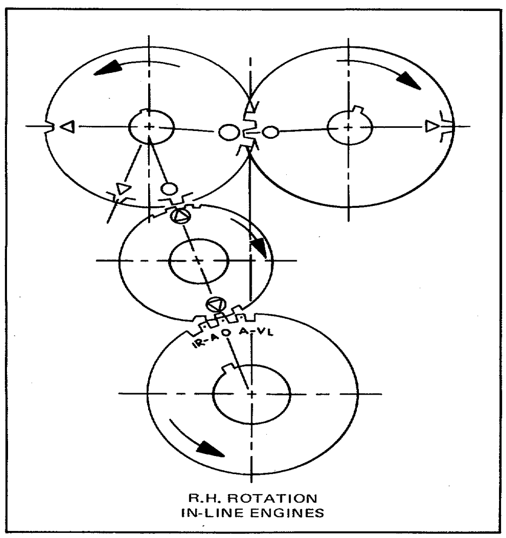


Figure 1. In-Line Engine Gear Train Timing Marks (Standard Timing Shown)

Effective with engine serial number 4D-65954, all Series 53 vehicle engines are built with advanced timing. The timing is advanced by aligning the proper A timing mark on the crankshaft gear with the circle-triangle timing mark on the idler gear.

The camshaft and balance shaft gears are positioned so that the circle timing marks are adjacent to each other (Fig. 1). One circle-triangle timing mark on the idler gear is aligned with the second circle on the mating camshaft (or balance shaft) gear. The other timing mark on the idler gear is aligned with the proper timing mark on the crankshaft gear.

The crankshaft gear is stamped IR-A on the left side of the circle timing mark (Fig. 1) for a right-hand rotation engine. For standard timing, the circle on the crankshaft gear is aligned with the circle-triangle on the idler gear. For advanced timing, the A adjacent to the IR on the crankshaft gear is aligned with the circle-triangle on the idler gear.

Lubrication

The gear train is lubricated by the overflow of oil from the camshaft and balance shaft pockets spilling into the gear train compartment. A certain amount of the oil also spills into the gear train compartment from the camshaft and balance shaft end bearings and the idler gear bearing. The blower drive gear bearing on the four-cylinder, in-line engine is lubricated through an external pipe leading from the cylinder block, main oil gallery to the gear hub support.

Engine Timing

The correct relationship between the crankshaft and camshaft(s) must be maintained to properly control fuel injection and the opening and closing of the exhaust valves.

The crankshaft timing gear can be mounted in only one position since it is keyed to the crankshaft. The camshaft gear(s) can also be mounted in only one position due to the location of the keyway relative to the cams. Therefore, when the engine is properly timed, the markings on the various gears will match as shown in Fig. 1.

Pre-ignition, uneven running, and a loss of power may result if an engine is out of time.

When an engine is suspected of being out of time due to an improperly assembled gear train, a quick check can be made without removing the flywheel and flywheel housing by following the procedure outlined below.

Check Engine Timing

Access to the crankshaft pulley, to mark the top dead center position of the selected piston, and to the front end of the crankshaft or the flywheel for turning the crankshaft is necessary when performing the timing check. Then proceed as follows:

1. Clean and remove the valve rocker cover.

2. Select any cylinder for the timing check.

3. Remove the injector as outlined in Fuel Injector.

4. Carefully slide a rod, approximately 12 inches long, through the injector tube until the end of the rod rests on top of the piston. Place the throttle in the no-fuel position. Then turn the crankshaft slowly in the direction of engine rotation. Stop when

the rod reaches the end of its upward travel. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.

5. Select a dial indicator with 0.001 inch graduations and a spindle movement of at least one inch. Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke. Also, select suitable mounting attachments for the indicator so it can be mounted over the injector tube in the cylinder head.

6. Mount the indicator over the injector tube. Check to be sure the indicator spindle extension is free in the injector tube and is free to travel at least one inch.

7. Attach a suitable pointer to the engine lower front cover. The outer end of the pointer should extend out over the top of the crankshaft pulley.

8. Turn the crankshaft slowly, in the direction of engine rotation, until the indicator hand just stops moving.

9. Continue to turn the crankshaft, in the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is 0.010 inch.

10. Scribe a line on the crankshaft pulley in line with the end of the pointer.

11. Slowly turn the crankshaft, opposite the direction of rotation, until the indicator hand stops moving.

12. Continue to turn the crankshaft, opposite the direction of rotation, until the indicator starts to move again. Now set the indicator on zero and continue to turn the crankshaft until the indicator reading is 0.010 inch.

13. Scribe the second line on the crankshaft pulley in line with the end of the pointer.

14. Scribe a third line on the pulley halfway between the first two lines. This is top dead center.

CAUTION

If the crankshaft pulley retaining bolt loosened up, tighten it to the torque specified in Specifications.

15. Remove the dial indicator and rod from the engine.

16. Install the injector as outlined in Fuel Injector. Then refer to Engine Tune-up and adjust the exhaust valve clearance and time the fuel injector.

17. Turn the crankshaft, in the direction of rotation, until the exhaust valves in the cylinder selected are completely open. Reinstall the dial indicator so the indicator spindle rests on the top of the injector follower. Then set the indicator on zero. Next, turn the crankshaft slowly, in the direction of rotation, until the center mark on the pulley is in line with the pointer.

18. Check the front end of the cam- shaft for an identification mark. For identification purposes, a letter V is stamped on each end of a low velocity camshaft, but a letter V is not stamped on a high velocity camshaft. Note the indicator reading and compare it with the dimensions listed in Table 1 for the particular camshaft in the engine.

19. Remove the dial indicator. Also remove the pointer attached to the front of the engine.

20. Install the valve rocker cover.

TABLE 1

Engine	*INDICATOR READING		
	Correct	Retarded 1 -Tooth	Advanced 1 -Tooth
	STANDARD TIMING		
(1)$_4$	0.228 inch	0.204 inch	0.245 inch
(2)$_4$	0.206 inch	0.179 inch	0.232 inch
	ADVANCED TIMING		
(2)$_4$	0.232 inch	0.206 inch	0.258 inch

*Indicator readings shown are nominal values. The allowable tolerance is ±0.005 inch.
(1)High-velocity type injector cam.
(2)Low-velocity type injector cam.

CAMSHAFT, BALANCE SHAFT, AND BEARINGS

The camshaft and balance shaft used in the in-line engines are located just below the top of the cylinder block. The camshaft and balance shaft in the in-line engines may be positioned on either side of the engine as required by the engine rotation and accessory arrangement.

The accurately ground cams ensure efficient, quiet cam follower roller ac- tion. They are also heat treated to provide a hard wear surface.

Both ends of the shafts are supported by bearings (bushing-type) that are pressed into bores in the cylinder block. The balance shaft is supported by front and rear bearings only, whereas the camshaft is supported by end, intermediate, and center bearings. Two end bearings (front and rear), two intermediate bearings, and a center bearing are used in the four-cylinder engines to support the camshafts.

To facilitate assembly, letters signifying the engine models in which a shaft may be used are metal stamped on the ends of the shaft. The letters on the timing gear end of the camshaft must correspond with the engine model. For example, the letters RC are stamped on a camshaft used in an RC-model engine. For additional identification, a camshaft with no designation on the ends or a 7 stamped on the ends is a high-velocity, high-lift camshaft. A camshaft metal stamped with a V or V7 is a low-velocity, high-lift camshaft. Effective with engine 4D-112278, new camshafts metal stamped V7L are used intermittently in the four in-line engines. These are low-velocity, low-lift camshafts.

On 4-53 engines, the present low-lift camshaft must be used in conjunction with the new exhaust valve springs. Refer to Exhaust Valves.

IMPORTANT

Failure to change the exhaust valve springs could result in broken springs and engine failure.

NOTE

The low-lift camshaft which provides a maximum valve cam lobe lift of 0.276 inch is stamped V7L on both ends.

To provide proper camshaft end thrust, a new front camshaft pulley spacer is being used and the oil slinger has been eliminated, effective with engine serial number 4D-164682. Engines built prior to 1968 were built with an oil slot broached in the camshaft end bearing. With pressure oil from this slot flowing directly on the upper front cover oil seal, the seal required the protection of an oil slinger. Even though the slot was eliminated in 1968, the use of the slinger was continued. With the elimination of the oil slinger, a new 0.025-inch longer spacer is used to make up for the removal of the slinger. Therefore, when removing the oil slinger(s) from an engine built prior to the above serial number, it will be necessary to replace the shorter spacer(s) with the new 0.025-inch longer spacer. Removal of the oil slinger on former engines is not mandatory.

NOTE

The former short spacer and slinger are for engines built prior to 1968 (engine serial number 4D-48900).

The new spacer is identified with a black oxide finish, the same part number also incorporates an optional material (powered metal) which is identified with an indent in the top surface below the chamfer.

A method of identifying a camshaft with the cylinder head still installed is as follows:

1. Put a dial indicator on the rocker arm clevis.

2. Bar the engine over 3600 and the indicator will give a reading directly relative to the maximum amount of lift on the high point of the camshaft exhaust lobe.

   a. The 4-53 low-lift camshafts have a 0.276-inch maximum lift.

   b. The 4-53 high-lift camshafts have a 0.327-inch maximum lift.

3. The above can be accomplished with the cylinder head removed by placing the dial indicator directly on the exhaust valve lobe of the camshaft. A reading of the maximum camshaft lift can be taken at the high point of the lobe.

Lubrication

Lubrication is supplied under pressure to the camshaft and balance shaft end bearings via oil passages branching off from the main oil gallery direct to the camshaft end bearings.

In addition, oil is forced through an oil passage in each camshaft which lubricates the camshaft intermediate bearings. On the current camshafts, the intermediate journal oil grooves were eliminated and a chamfer added to the intermediate journal oilholes. When replacing a former camshaft with a current camshaft, always use new bearings.

All of the camshaft and balance shaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

Remove Camshaft or Balance Shaft

Whenever an engine is being completely reconditioned or the bearings, thrust washers, or the gears need replacing, remove the shafts from the engine as follows:

NOTE

Refer to Shop Notes to install a cup plug in the front end of the camshaft.

1. Drain the engine cooling system.

2. Remove all accessories and as- semblies with their attaching parts as necessary to permit the engine to be mounted on an overhaul stand (See Cylinder Block).

3. Mount the engine on an overhaul stand.

IMPORTANT

Be sure the engine is securely mounted on the stand before releasing the lifting sling.

4. Remove the cylinder head(s). Refer to Cylinder Head.

5. Remove the flywheel and the fly- wheel housing as outlined in Flywheel and Flywheel Housing.

6. Remove the bolts which secure the gear nut retainer plates (if used) to the gears, then remove the retainer plates.

7. Wedge a clean rag between the gears as shown in Fig. 1, and remove the nuts from each end of both shafts with a socket wrench.

8. Remove the balance pulleys from the front end of the shafts as outlined Engine Balance.

9. Remove the upper engine front cover

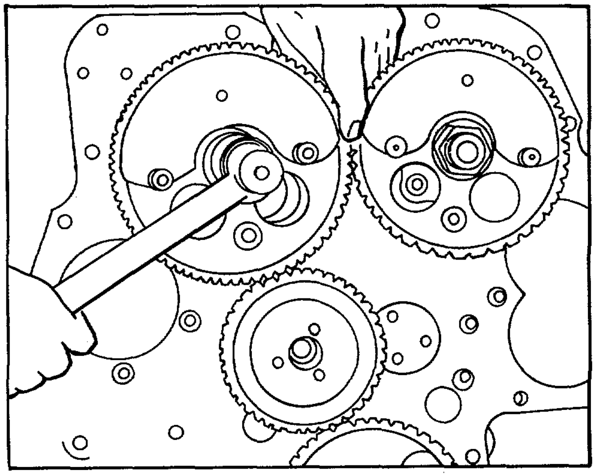


Figure 1. Removing or Installing Nut on Camshaft or Balance Shaft

10. Remove the oil slinger from the front end of both shafts.

11. Remove the two retaining bolts that secure the camshaft or balance shaft thrust washer to the cylinder block by inserting a socket wrench through a hole in the web of the gear as shown in Fig. 2.

12. Withdraw the shaft, thrust washer, and gear as an assembly from the rear end of the cylinder block.

Remove Camshaft (Flywheel Housing and Transmission in Place)

A camshaft may be removed and replaced without removing the flywheel housing and disconnecting the transmission, if there is space enough to slide the shaft out through the front of the engine.

1. Drain the cooling system.

2. Remove the accessories and as- semblies with their attaching parts that are necessary to facilitate the removal of the flywheel housing hole cover over the camshaft and the upper engine front cover (if used).

3. Remove the cylinder head.

4. Remove the gear nut retainer plates (if used).

5. Wedge a clean rag between the gears (Fig. 1) and remove the gear retaining nut from each end of the camshaft.

6. Remove the camshaft front balance pulley.

7. Remove the upper engine front cover (if used).

8. Remove the woodruff key from the camshaft and then remove the oil slinger.

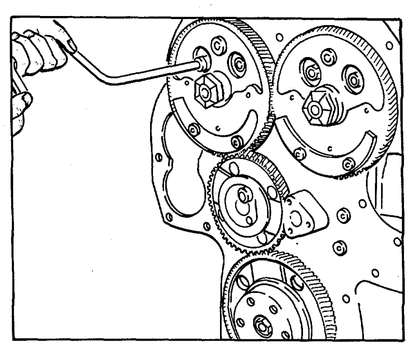


Figure 2. Removing or Installing Thrust Washer Retaining Bolts

9. Install camshaft gear puller J 1902-01, four spacers J 6202-2, and camshaft gear puller adaptor plate J 6202-1 on the camshaft gear (Fig. 3).

10. Turn the center screw of the puller clockwise to disengage the camshaft gear.

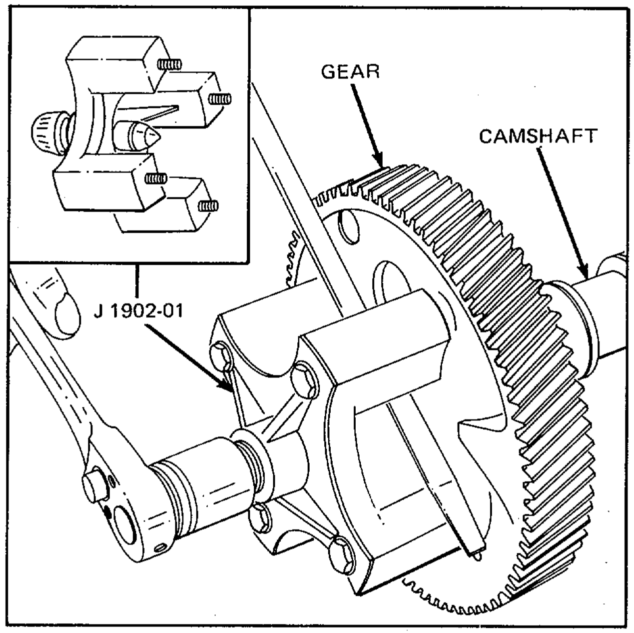


Figure 3.. Removing Camshaft Gear

NOTE

Do not remove the puller or the adaptor plate until the camshaft is reinstalled.. The adaptor plate, secured to both the flywheel housing and the camshaft gear, will hold the gear securely in place and in alignment which will aid in the reinstallation of the camshaft.

11.. Pull the camshaft from the cylinder block.

Disassemble Camshaft or Balance Shaft

1.. Remove the gear from the shaft.. Refer to Camshaft and Gears.

2.. Remove the end plugs from the camshaft, to facilitate the removal of any foreign material lodged behind the plugs, as follows:

a.. Clamp the camshaft in a vise equipped with soft jaws, being careful not to damage the cam lobes or machined surfaces of the shaft.

b.. Make an indentation in the center of the camshaft end plug with a 31/64-inch drill (carboloy tip).

c.. Punch a hole as deeply as possible with a center punch to aid in breaking through the hardened surface of the plug.

d.. Then drill a hole straight through the center of the plug with a 1/4-inch drill (carboloy tip).

e.. Use the 1/4-inch drilled hole as a guide and redrill the plug with a 5/16-inch drill (carboloy tip).

f.. Tap the drilled hole with a 3/8-16 tap.

g.. Thread a 3/8-16 adaptor J 64712 into the plug.. Then attach slide hammer J 2619-5 to the adaptor and remove the plug by striking the weight against the handle.

h.. Insert a length of 3/8-inch steel rod in the camshaft oil gallery and drive the remaining plug out.

NOTE

If a steel rod is not available, remove the remaining plug as outlined in steps a through g.

Inspection

Soak the camshaft in clean fuel oil. Then run a wire brush through the oil gallery to remove any foreign material or sludge. Clean the exterior of the camshaft and blow out the oil gallery and the oilholes with compressed air. Clean the gears, camshaft bearings, and related parts with fuel oil and dry them with compressed air.

Inspect the cams and journals for wear or scoring. If the cams are scored, inspect the cam rollers as outlined in Valve operating Mechanism.

If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of cam lobe wear as follows:

NOTE

The camshaft can be in or out of the engine during this inspection.

1. With a tapered leaf set of feeler gages (0.0015-0.0100 inch) and a piece of square hard material 1/8 x 3/8 x 1 inch measure the flat on the injector rise side of the cam lobes (Fig. 4).

2. If the flats measure less than 0.003 inch in depth and there are no other defects, the camshaft is satisfactory for service.

3. A slightly worn lobe still within acceptable limits may be stoned and smoothed over with a fine crocus cloth.

Check the runout at the center bearing with the camshaft mounted on the end bearing surfaces. Runout should not exceed 0.002 inch.

Examine both faces of the thrust washers. If either face is scored or if the thrust washers are worn excessively, replace the washers. New thrust washers are 0.208 to 0.210 inch thick.

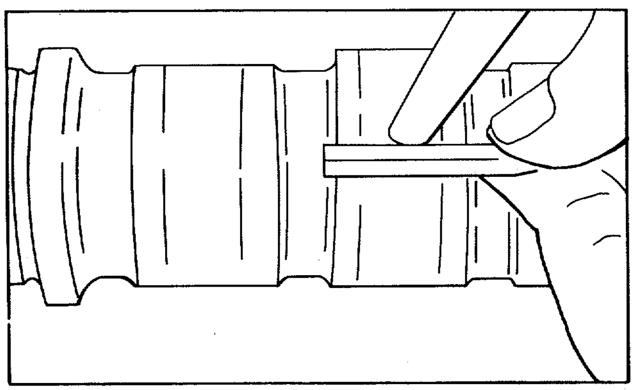


Figure 4. Checking Cam Lobe Wear

Also, examine the surfaces which the thrust washers contact; if these surfaces are scratched but not severely scored, smooth them down with an oil stone. If the score marks are too deep to be removed, or if parts are badly worn, use new parts.

CAUTION

If a new camshaft is to be installed, steam clean it to remove the rust preventive and blow out the oil passages with compressed air.

The clearance between new shafts and new bearings is 0.0045 to 0.006 inch, or a maximum of 0.008 inch with worn parts. Excessive clearance between the shafts and the bearings will cause low oil pressure and excessive backlash between the gears.

Bearings are available in 0.010 inch and 0.020 inch undersize for use with worn or reground shafts.

Oversize camshaft and balance shaft bearings are available in sets, 0.010 inch oversize on the outside diameter, to permit reuse of a cylinder block having one or more scored block bearing bores. To use the oversize bearings, the camshaft and balance shaft block bores must be carefully line-bored (machined) to the dimensions shown in Table 1.

Remove Bearings

The end bearings must be removed prior to removing the intermediate bearings.

CAUTION

When removing the bearings be sure to note the position of the bearings in the bore with respect to the notch in the bearings. Replacement bearings must be installed in the same position.

TABLE 1

CAMSHAFT AND BALANCE SHAFT CYLINDER
BLOCK BORE HACHINING CHART
(Oversize Camshaft Bearings)

Engine	Bearing Location	Dimension	
		Minimum	Maximum
4	End	2.385 inch	2.386 inch
4	Intermediate	2.375 inch	2.376 inch
4	Center	2.365 inch	2.366 inch

1. Remove all accessories and assemblies with their attaching parts as is necessary so that tool set J 7593-03 inay be used as shown in Fig. 5 and in A of Fig. 9.

Tool set J'7593-03, designed for use with standard size bearings, may be used to remove and install 0.010 inch undersize and 0.020 inch undersize bearings by reducing the pilot diameter of the pilot J 7593-2, installer J 7593-3, remover J 7593-5, installer J 7593-6, and installer J 7593-15. The pilot diameter of these tools should be reduced by 0.020 inch. This reduction in tool diameter does not materially effect usage on standard size bearings. If the tools are used frequently, however, it may be advisable to purchase additional standard pieces. Reduced diameter tools have not been released.

2. Insert the small diameter end of pilot J 7593-2 into the end bearing.

3. Then, with the unthreaded end of shaft J 7593-1 started through the pilot, push the shaft through the block bore until the end of the shaft snaps into remover J 7593-5.

4. tlow drive the end bearing out of the cylinder block. The nearest intermediate and/or center bearings can be removed in the saine manner. The large diameter end of pilot J 7593-2 will fit into the camshaft bore and is used when removing the other end bearing and any remaining bearings.

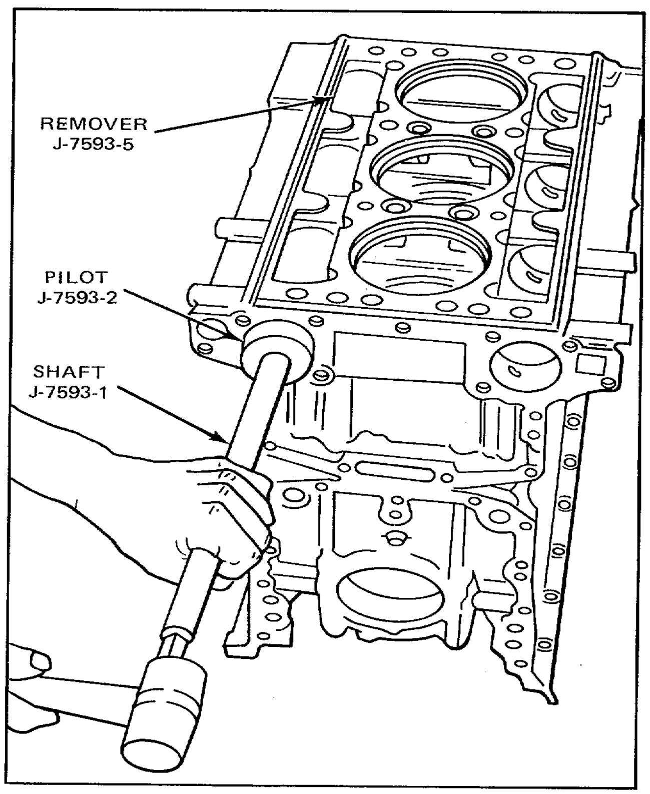


Figure 5. Removing End Bearing

Install Intermediate and/or Center Camshaft Bearings

Camshaft center and intermediate bearings mrust be installed prior to installing the camshaft end bearings. On the four-cylinder in-line engine, the center, rear intermediate and rear bearings are installed in that order by pressing the bearings from the rear to the front of the block. The front internediate and front beartngs are installed by pressing the bearings from the front to the rear of the block.

NOTE

Current bearings incorporate lubrication grooves on the inner bearing surface (Fig. 7).

To properly install the camshaft and balance shaft bearings, refer to Fig. 8 for location of the notch in the bearing in relation to the camshaft or balance shaft bore centerline in the cyLinder block.

Also, to facilitate assembly, the camshaft and balance shaft bearings are color coded on the side and/or end as shown in Table 2.

1. Insert pilot J 7593-2 in the bore of the block as shown in Fig. 6. Use the small end of the pilot if an end bearing has been installed. Refer to B and C of Fig. 9.

2. Insert the new intermediate or center bearing into the camshaft bore and position it correctly. Install the center bearing first.

TABLE 2

CAMSHAFT AND BALANCE SHAFT
BEARING COLOR CODE CHART

Bearing Position	Color Code		Outside Diameter	Inside Diameter
	Current	Former		
End	Brown	Black	Standard	Standard 0.010 inch & 0.020 inch U.S.
	Brown	Yellow	0.010 inch Oversize	Standard (only)
Intermediate	Orange	Red	Standard	Standard 0.010 inch & 0.020 inch U.S.
	Orange	Blue	0.010 inch Oversize	Standard (only)
Center	White	Green	Standard	Standard 0.010 inch & 0.020 inch U.S.
	White	Red	0.010 inch Oversize	Standard*

*The former red center bearing of the standard set is also used as the intermediate bearing of the oversize (0D.) set.

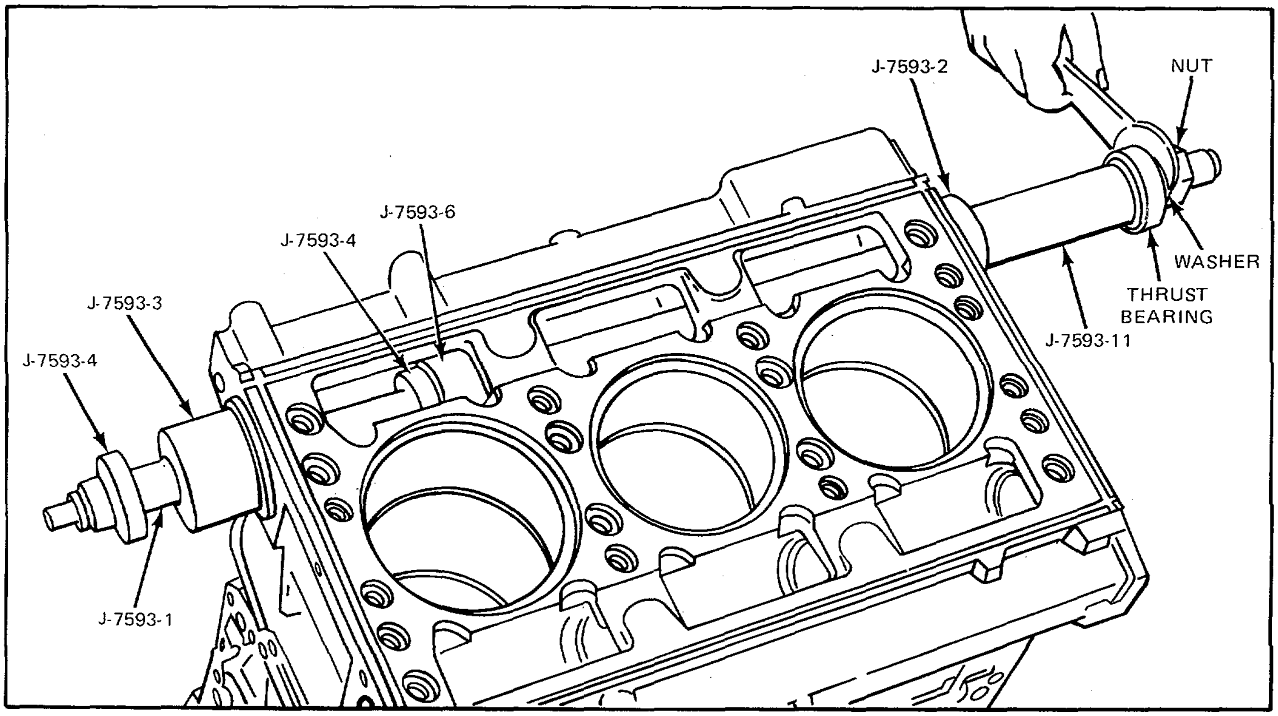


Figure 6. Installing Intermediate Camshaft Bearing

3. Then, with the unthreaded end of shaft J 7593-1 started through the pilot, push the shaft through the entire length of the block bore.

4. Slide installer J 7593-6 on the shaft until the locating pin registers with the notch in the bearing. Then slide installer J 7593-3 or J 7593-15 on the shaft with the large diameter inserted into the end of the block bore. Refer to C and note of Fig. 9.

5. Next, place a spacer (if required), thrust washer, plain washer, and hex nut over the threaded end of the puller.

6. Align the shaft in such a way that a C-washer J 7593-4 can be inserted in a groove in the shaft adjacent to installer J 7593-6.

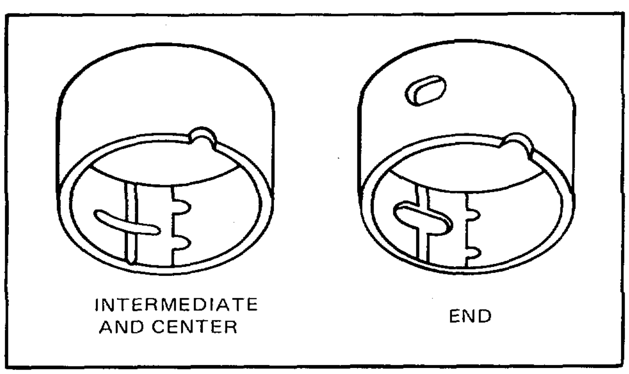


Figure 7. Camshaft and Balance Shaft Bearing Identification

7. Place a C-washer in the groove near the end of the shaft and, using a suitable wrench on the hex nut, draw the bearing into place until the Cwasher butts up against installer J 7593-3 and prevents the shaft from further movement.

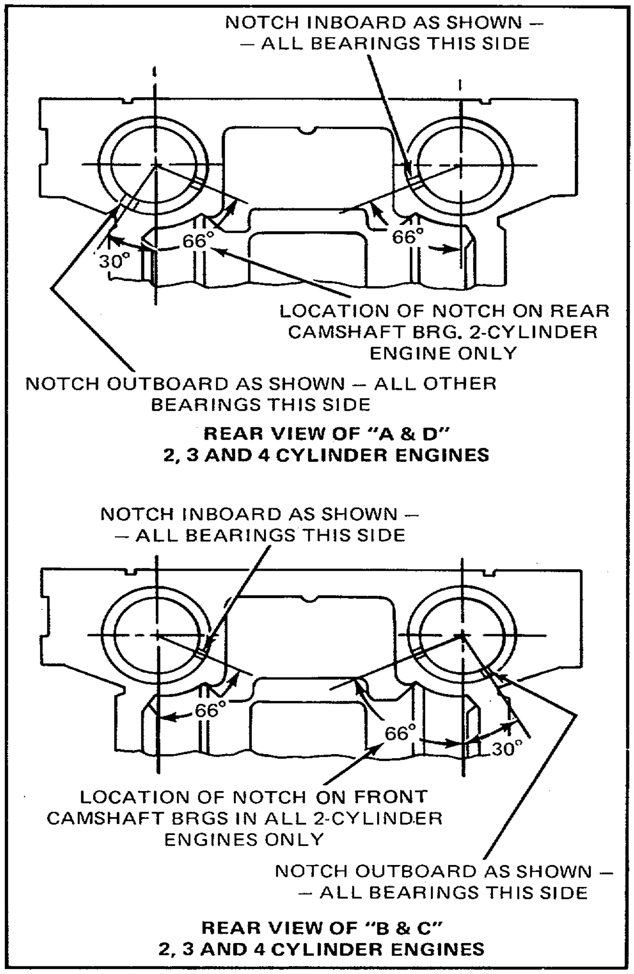


Figure 8. Location of Notch in Relation to Shaft Bore Centerline

Install End Bearings

Refer to the camshaft and balance shaft color code chart and the cylinder block bore machining dimension chart when installing the end bearings.

1. Insert pilot J 7593-2 in the bore of the block as shown in D of Fig. 9. Use the small diameter of the pilot if a bearing has been installed.

2. Insert support J 7593-12 in the bore in the opposite end of the block. Then, with the unthreaded end of the shaft started through pilot J 7593-2, push the shaft through the block and support J 7593-12.

3. Place a new end bearing on installer J 7593-3 and align the notch in the bearings with the pin on the installer. Then slide the installer and the bearing on the shaft. Position the bearing correctly with the groove in the camshaft bore.

4. Place C-washer J 7593-4 in the end notch in the shaft; pull the shaft back until the washer butts against the installer.

5. Next, place a spacer (if required), thrust washer, plain washer, and hex nut over the threaded end of the shaft as shown in D of Fig. 9 and, using a suitable wrench on the hex nut, draw the bearing into place until the shoulder on the installer prevents the shaft from further movement. The bearing is now installed in its correct position.

Install the remaining end bearings in the same manner.

Use of tool set J 7593-03 assures that the bearings are properly spaced in relation to the end of the block. The center bearing (notch end) for a four-cylinder block is 10.94 inches from the rear face of the block. The intermediate bearings for the four-cylinder block are 5. 54 inches from the rear and front face of the block.

Assemble and Install Camshaft and Balance Shaft

Refer to Fig. 10 and assemble the camshaft and balance shaft.

1. Install new end plugs in the camshaft. Press the plugs in to a depth of 1. 940 to 2. 060 inches (Fig. 11).

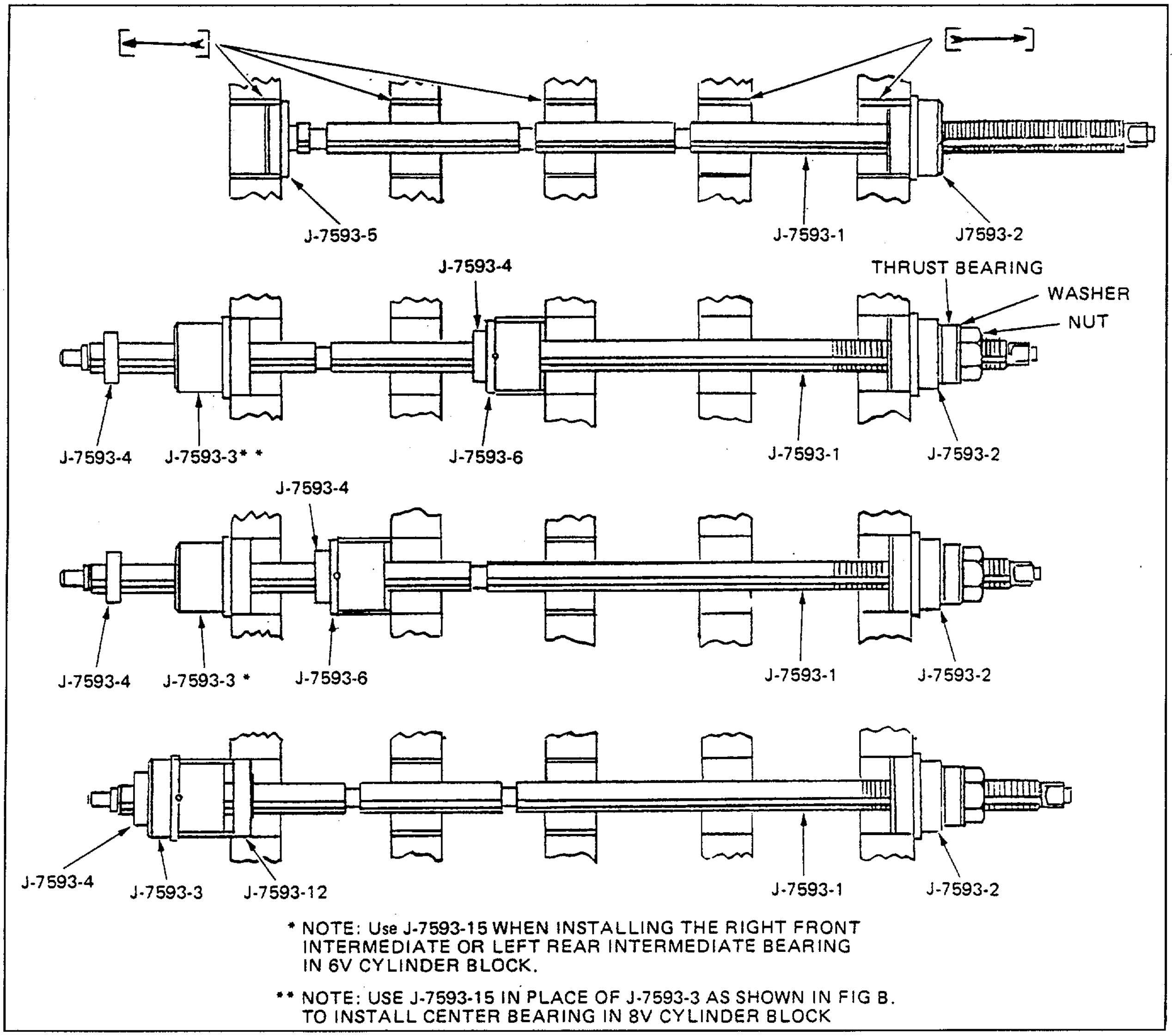


Figure 9. Removing and Replacing Camshaft or Balance Shaft Bearings

2. Install the gears and thrust washers on their respective shafts as outlined in Camshaft and Gears.

3. Lubricate the bearings and shafts with engine oil and slide the shaft assemblies into the cylinder block, being careful not to damage the bearings or the cams and journals. Make sure that the appropriate timing marks on the gears are aligned. Refer to Gear Train and Engine Timing. 4. Slide an oil slinger on the front end of both shafts.

5. Install the upper engine front cover, if used (Front Cover).

6. Secure the thrust washers in place as shown in Fig. 2 and tighten the bolts to 30-35 lb ft (41-47 Nm) torque.

7. Install the front balance weights (Gear Train and Timing).

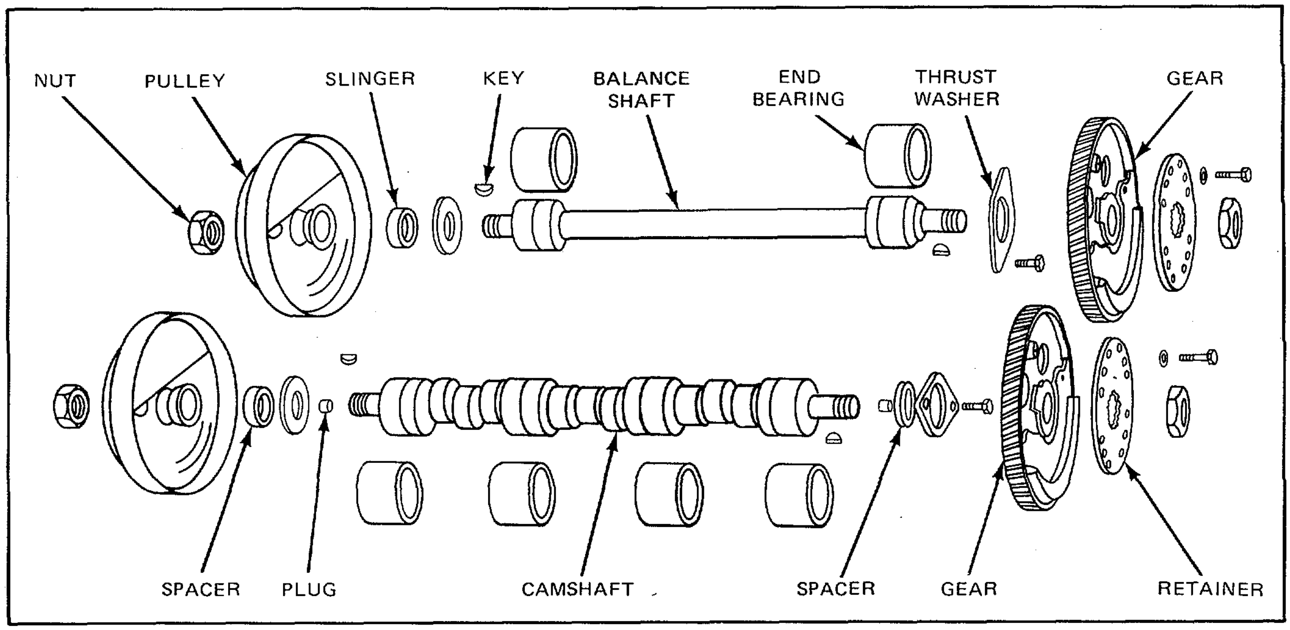


Figure 10. Camshaft and Balance Shaft Details and Relative Location of Parts

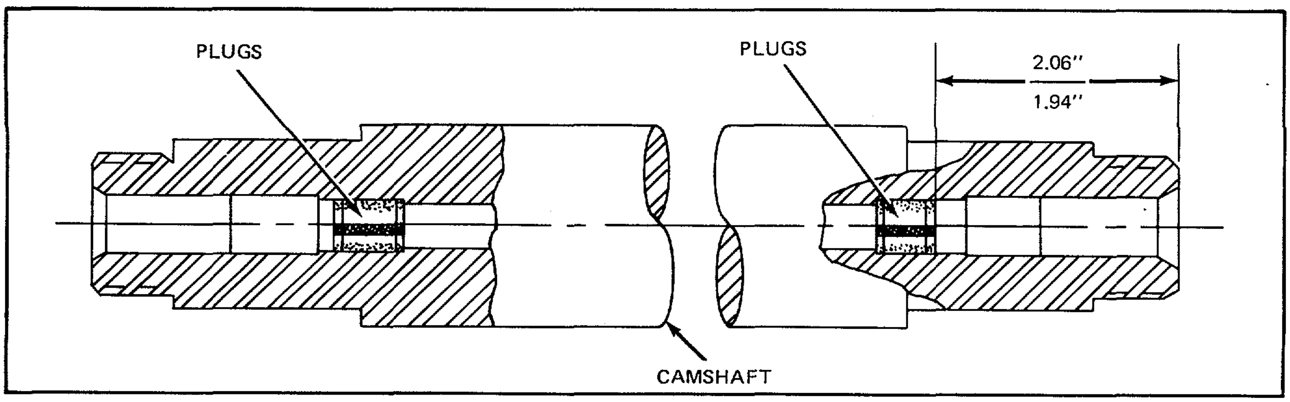


Figure 11. Camshaft Plug Iristallation

8. Attach the gear nut retainer plates (if used) to the gears with bolts and lockwashers, and tighten the bolts to 35-39 lb ft (47-53 Nm) torque.

9. Check the clearance between the thrust washer and the gear on both shafts. The clearance should be 0.005 to 0.015 inch, or a maximum of 0.019 inch with used parts.

10. Check the backlash between the mating gears. The backlash should be 0. 003 to 0.005 inch and should not exceed 0.007 inch between used gears.

11. Install the flywheel housing and other parts or assemblies that were removed from the engine as outlined in their respective sections of this manual.

Install Camshaft (Flywheel Housing and Transmission in Place)

1. Place the rear camshaft spacer over the end of the camshaft and install the woodruff key in the gear end of the camshaft. Insert this end into position from the front of the engine. Push the shaft in until it slides into the end bearing.

2. Ali. gn the key in the shaft with the keyway in the camshaft gear and start the shaft into the gear. Tap the shaft into the gear with a soft (plastic or rawhide) hammer.

3. Remove the camshaft gear puller, spacers, and adaptor plate. Finger tighten the gear retaining nut on the shaft.

4. Install the oil slinger on the front end of the camshaft.

5. Install the upper front cover, if used, and slide the spacer over the end of the camshaft and into the oil seal in the cover.

6. Install the camshaft front balance pulley. Finger tighten the pulley retaining nut.

7. With the clean rag wedged between the gears to prevent their rotation, tighten the nut on each end of the camshaft to 300-325 lb ft (407-441 Nm) torque.

8. Install the gear nut retainers with bolts and lockwashers. Tighten the bolts to 35-39 lb ft (47-53 Nm) torque.

9. Install the accessories and assemblies that were removed and refill the cooling system.

CAMSHAFT AND BAIANCE SHAFT GEARS

The camshaft and balance. shaft gears on an in-line engine are located at the flywheel end of the engine and mesh with each other and run at the same speed as the crankshaft.

Sixnce the camshaft and balance shaft gears on in-line engines must be in time with each other, timing marks are stamped on the rim of each gear. Also, since these two gears as a unit must be in time with the crankshaft, timing marks are located on the idler and crankshaft gears (refer to Gear Train and Timing).

Each gear is keyed to its respective shaft and held securely against the shoulder on the shaft by a nut. A gear nut retainer, with a double-hexagon hole in the center, fits over the nut on some engines. The retainer is attached to the gear by bolts threaded into tapped holes in the gear.

On the four-cylinder in-line engines, external weights are attached to the rear face of each gear. The weights are important in maintaining perfect engine balance.

When new service gears are used on an in-line engine, the external weights on the old gears must be transferred to the new gears. If the weights are transferred to new gears, tighten the bolts to 45-50 lb ft (61-68 Nm) torque.

Remove Camshaft and Balance Shaft Gears

1. Remove the camshaft and the balance shaft from the engine as outlined in Camshaft and Bearings.

2. Place the camshaft and gear assembly in an arbor press with the gear suitably supported as shown in Fig. 1.

3. Place a woodblock under the lower end of the camshaft so the threads will not be damaged when the shaft is pressed from the gear.

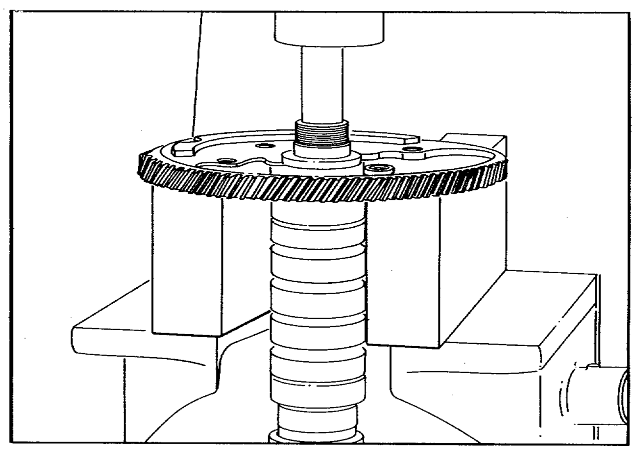


Figure 1. Removing Camshaft Gear

4. Place a short piece of 3/4-inch O.D. brass rod on the end of the camshaft and press the camshaft out of the camshaft gear.

5. Remove the thrust washer, woodruff key, and spacer from the camshaft.

6. Remove the gear from the balance shaft in a similar manner.

Inspection

Clean the gears with fuel oil and dry them with compressed air. Then examine the gear teeth for evidence of scoring, pitting, and wear. Replace the gears if necessary.

Examine both faces of the camshaft and balance shaft thrust washer and, if either face is worn or scored, replace the washer. Also examine the surface on the camshaft and balance shaft which the thrust washer contacts. If this surface is scratched, but not severely scored, smooth it up with a fine oil stone.

Install Camshaft and Balance Shaft Gears

1. Note the letters stamped on the end of the camshaft which signify the engine models in which a camshaft may be used. The letters on the timing gear end of the camshaft must correspond with the engine model of--the particular engine being assembled. Refer to the front of this manual for engine rmodel identification.

2. Place the rear camshaft spacer over the timing gear end of the camshaft and install the woodruff key.

3. Lubricate the thrust washer with clean engine oil and place the thrust washer over the gear end of the camshaft and the spacer.

4. Start the camshaft gear over the end of the camshaft with the key in the shaft registering with the keyway in the gear.

5. Then, with the camshaft supported in an arbor press, place a sleeve on top of the gear and press the gear tight against the spacer on the shaft (Fig. 2).

6. Measure the clearance between the camshaft thrust washer and the camshaft. This clearance should be 0.008 to 0.015 inch when new parts are used. With used parts, a maximum clearance of 0.021 inch is allowable.

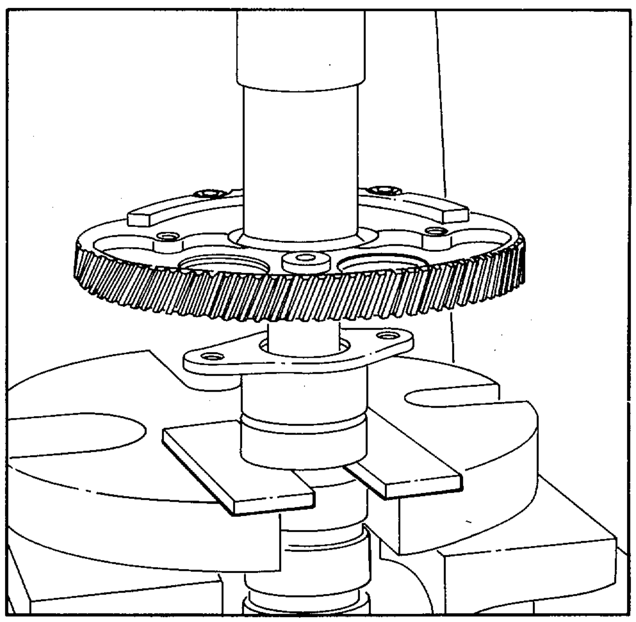


Figure 2. Installing Camshaft Gear

7. Install the gear retaining nut on the camshaft by hand. Tighten the nut after the shaft is installed in the cylinder block.

8. Install the gear on the balance shaft in a similar manner. No rear spacer is used with the balance shaft gear since the gear seats against a shoulder on the shaft.

9. Install the camshaft and balance shaft in the engine as outlined in *Camshaft and Bearings*.

IDLER GEAR AND BEARING ASSEMBLY

The engine idler gear and bearing assembly, located at the flywheel end of the engine, meshes with the camshaft and crankshaft gears and rotates on a stationary hub. The hub is secured directly to the cylinder block by a bolt which passes through the hub and three bolts which pass through the flywheel housing, hub, and end plate (Fig. 1).

Two timing marks (a triangle within a circle) are stamped on the idler gear diametrically opposite (180°) to one another.

The inside diameter of the idler gear bearing is 2. 186 to 2. 187 inches and the outside diameter of the idler gear hub is 2. 1825 to 2. 1835 inches. Therefore, the clearance between the idler gear hub and the idler gear bearing is 0.0025 to 0.0045 inch, with a maximum allowable wear limit of 0.007 inch.

A thrust washer is provided on both sides of the idler gear and bearing assembly. The standard thickness of the idler gear and bearing assembly is 1. 233 to 1. 234 inches and the standard thickness of the two thrust washers is 0.236 to 0.240 inch. Therefore, the clearance between the thrust washers and the idler gear is 0.006 to 0.013 inch, with a maximum allowable wear limit of 0.017 inch.

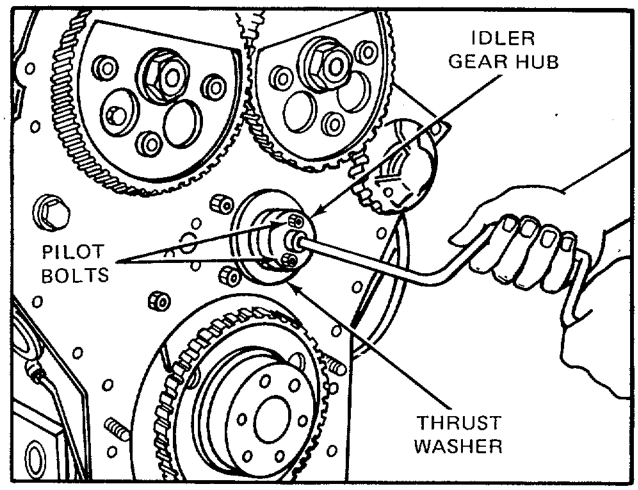


Figure 1. Installing Idler Gear Hub

On an in-line engine, the idler gear is positioned on the left-hand side for a right-hand rotating engine and on the right-hand side for a left-hand rotating engine as viewed from the rear.

On early engines, an idler gear spacer (dummy hub) was used on the side opposite the idler gear. Currently the flywheel housing has an integral cast hub and a 0.015-inch thick shim is used between the flywheel housing and the end plate.

Remove Idler Gear and Bearing Assembly (Flywheel Housing Removed)

1. Remove the idler gear outer thrust washer from the idler gear hub (Fig. 3).
2. Slide the idler gear straight back off of the idler gear hub.
3. Remove the bolt which secures the idler gear hub to the cylinder block. Then remove the idler gear hub and the idler gear inner thrust washer as an assembly.

Inspection

Wash the idler gear and bearing assembly, hub, and thrust washers thoroughly in clean fuel oil and dry them with compressed air. Examine the gear teeth and bearing for scoring, pitting, or wear. If the gear teeth are worn or the bearing is scored, pitted, or worn excessively, replace the gear and bearing assembly or install a new bearing in the gear. Examine the outside diameter of the idler gear hub and thrust washers. If scored or worn excessively, replace them.

IDLER GEAR

An idler gear bearing with two oil grooves has been incorporated in the idler gear and bearing assemblies, beginning with engine serial number 4D-9458.

When a new bearing (bushing) is installed in the idler gear, it must not protrude beyond the gear face on either side and must sustain an axial load of 2000 pounds (9. 07 kN) minimum without pushing out of the gear.

Install Idler Gear and Beariug Assembly

1. Place the inner thrust washer on the forward end of the idler gear hub with the flat in the inner diameter of the thrust washer over the flat on the end of the gear hub and with the oil grooves in the thrust washer facing the idler gear.

2. Place the small protruding end of the idler gear hub through the end plate and into the counterbore in the cylinder block.

3. Insert two 3/8-16 bolts through the idler gear hub and thread them into the cylinder block, as shown in Fig. 1, to be sure the boltholes will be in alignment when the flywheel housing is installed.

4. Insert the 3/8-16 x 1-3/4-inches long special bolt through the center of the idler gear hub and thread it into the cylinder block. Tighten the bolt to 40-45 lb ft (54-61 Nm) torque. Then remove the two 3/8-16 bolts previously installed for alignment of the gear hub.

5. Lubricate the idler gear hub and idler gear bearings liberally with clean engine oil.

6. Position the crankshaft gear and the camshaft gear or balance shaft gear so that their timing marks will align with those on the idler gear.

7. With these timing marks in alignment, install the idler gear as shown in Fig. 2.

8. Apply a thin film of cup grease to the inner face (face with the oil grooves) of the outer idler gear thrust washer. Then place the thrust washer over the end of the idler gear hub with the oil grooves in the side of the thrust washer facing the idler gear, and the flat in the inner diameter of the thrust washer over the flat on the end of the idler gear hub.

9. Check the backlash between the mating gears. The backlash should be 0.003 to 0.005 inch between new gears and should not exceed 0.007 inch between used gears.

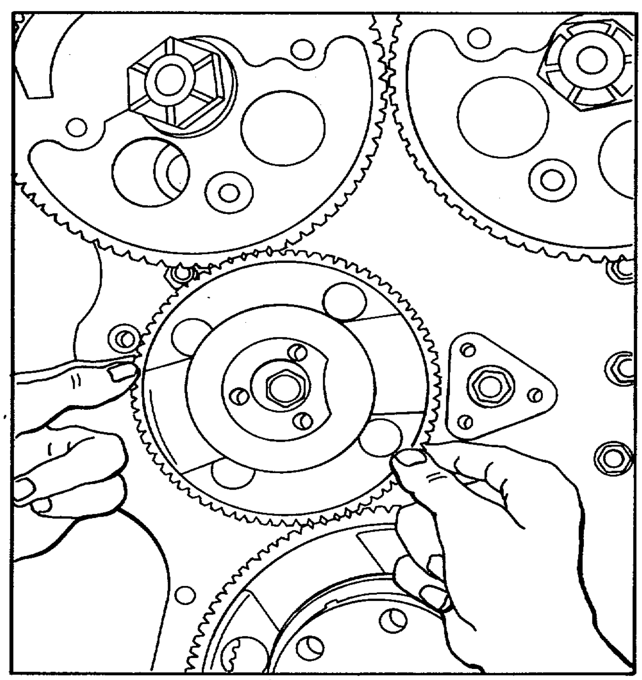


Figure 2. Installing Idler Gear

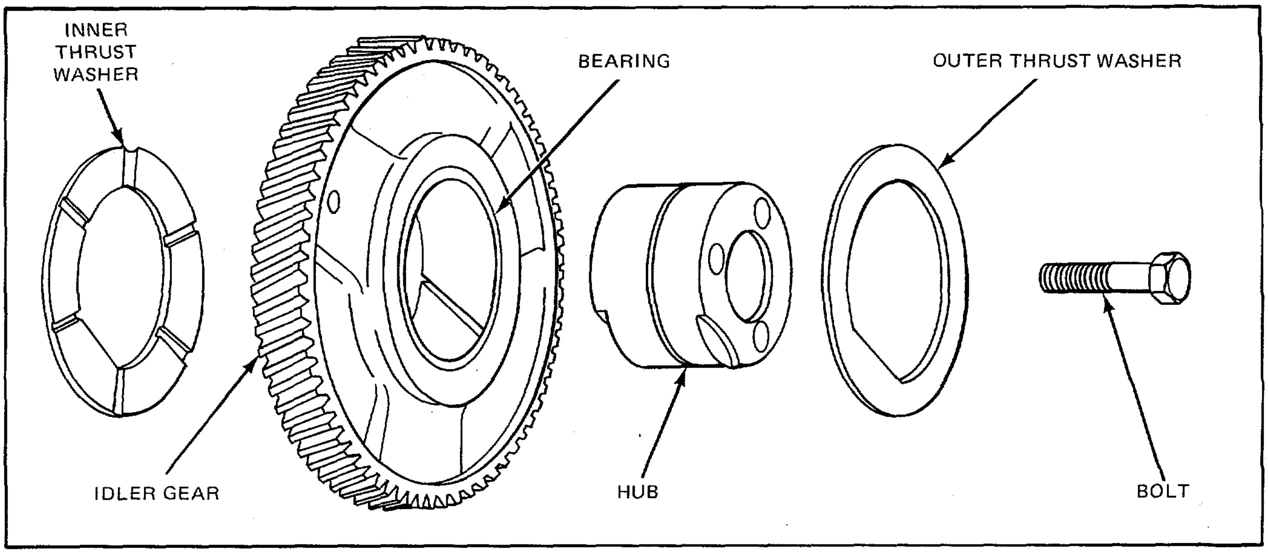


Figure 3. Idler Gear Details and Relative Location of Parts

CRANKSHAFT TIMING GEAR

The crankshaft timing gear is keyed and pressed on the crankshaft and drives the camshaft gear or balance shaft gear through an idler gear.

Since the camshaft must be in time with the crankshaft, timing marks are located on the rim of the idler gear with corresponding timing marks stamped on the crankshaft gear and camshaft and balance shaft gears (refer to Gear Train and Timing).

Remove Crankshaft Timing Gear (Flywheel Housing Removed)

The crankshaft timing gear is a 0 001 to 0 003-inch press fit on the crankshaft. The crankshaft diameter at this point is 4. 060 to 4. 061 inches. Remove the gear as follows:

1. Remove the crankshaft rear oil seal sleeve, if used. To remove the sleeve, peen the outside diameter of the sleeve until it stretches sufficiently so it can be slipped off the crankshaft.

2. Before removing the crankshaft gear, align the timing marks of the gear train and note their location so the gear can be reinstalled in its original position.

3. Attach bar-type puller J 4871 to the crankshaft gear with three long bolts or hooks, flat washers, and nuts through the holes in the gear as shown in Fig. 1.

4. Turn the center screw of the puller to pull the crankshaft gear off the crankshaft.

Inspection

Clean the gear with fuel oil and dry it with compressed air. Examine the gear teeth for evidence of scoring, pitting, or wear. If severely damaged or worn, install a new gear. Also check the other gears in the gear train.

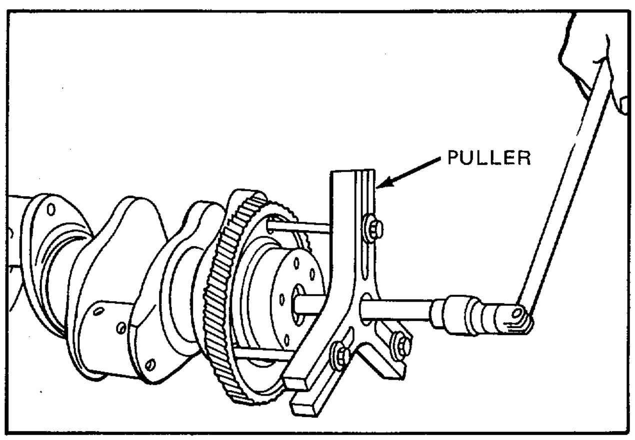


Figure 1. Removing Crankshaft Timing Gear

Install Crankshaft Timing Gear

1. If removed, install the woodruff key in the keyway in the crankshaft.

2. Start the timing gear over the end of the crankshaft with the timing inarks on the outer rim of the gear facing out and the keyway in the gear in alignment with the woodruff key in the crankshaft.

3. Align the proper timing mark on the crankshaft gear with the corresponding mark on the idler gear (refer to Gear Train and Timing).

NOTE

When advanced timing is required, align the timing mark "A" with the timing mark on the idler gear.

4. Place a heavy hammer against the head of the bolt in the front end of the crankshaft. Place installer J 7557 against the rear face of the timing

gear aad drive the gear up against the shoulder on the crankshaft as shown in Fig. 2.

5. Check the gear backlash with the rnating gear. The backlash should be 0.003 to 0.005 inch with new gears or 0.007 inch imaximum with used gears.

6. Install a new crankshaft rear oil seal sleeve, if required, as outlined in Crankshaft Oil Seals.

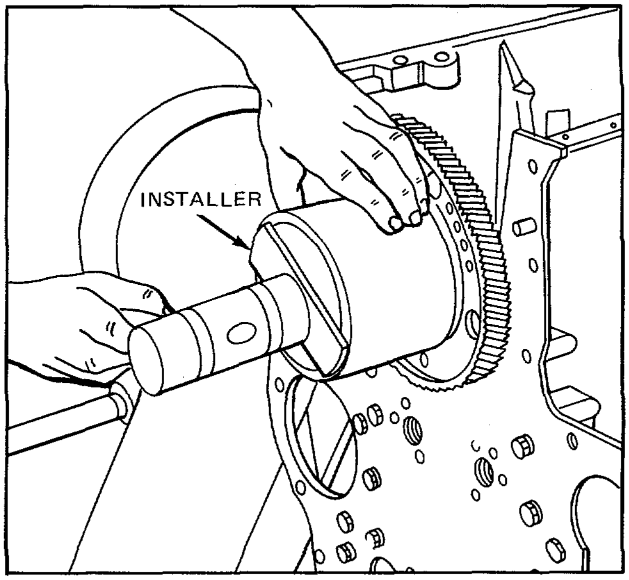


Figure 2. Installing Crankshaft Timing Gear.

BLOWER DRIVE GEAR AND SUPPORT ASSEMBLY

The blower drive gear is driven by the camshaft gear (4-53 engine). The gear is keyed and pressed on a shaft which is supported in the blower drive support. This support, on a 4-53 engine, is attached to the rear end plate on the blower side of the engine (Fig. 1).

Remove and Install Blower Drive Shaft

1. Remove the air inlet housing from the blower (refer to Air Shutdown Housing).
2. Refer to Fig. 1 and loosen the blower drive seal clamp.
3. Slide the clamp and seal off of the blower drive support.

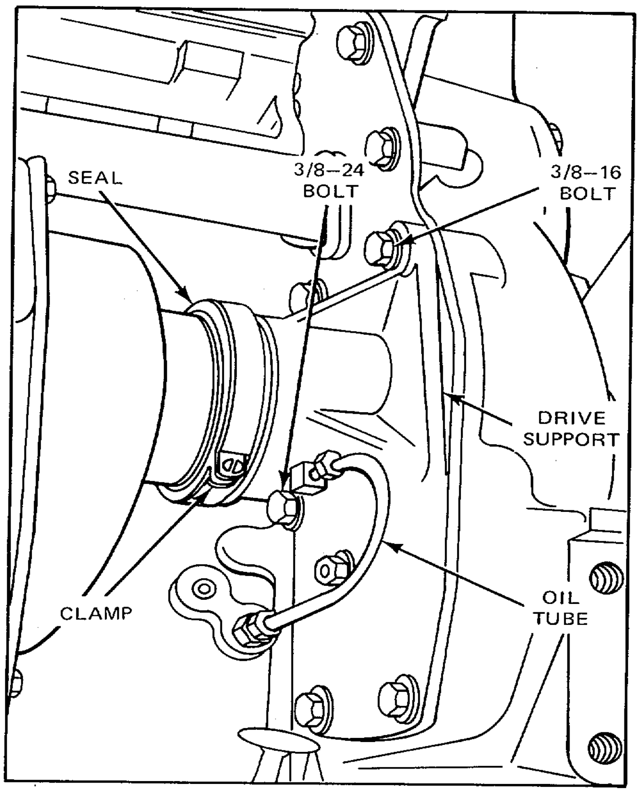


Figure 1. Blower Drive Support Mounting on 4-53 In-Line Engine

4. Remove the four blower-to-block bolts. Then carefully lift the blower away from the blower drive support and the cylinder block so the serrations on the blower drive shaft are not damaged.
5. Withdraw the blower drive shaft from the blower drive support.
6. Install the shaft by reversing the removal procedure.

Remove Blower Drive Support

1. Remove the blower and the blower drive shaft as outlined above.
2. Disconnect the lubricating oil tube (Fig. 1) from the blower drive support.
3. Remove the blower drive support attaching bolts.
4. Tap the blower drive support to loosen it, then carefully withdraw the support from the rear end plate so the blower drive gear teeth will not be damaged.

Disassemble Blower Drive Support

1. Remove the snapring and the thrust washer from the shaft.
2. If there are burrs on the edges of the snapring groove, remove them with a stone. Then withdraw the gear and shaft from the support.
3. Support the blower drive gear in an arbor press (Fig. 2).
4. Place a short, 1-1/8-inch diameter brass rod on the end of the shaft and press the shaft out of the gear.

Inspection

Thoroughly clean the parts with fuel oil and dry them with compressed air.

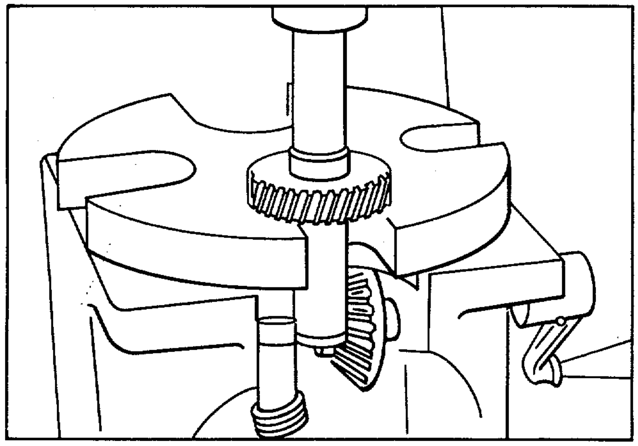


Figure 2. Pressing Blower Drive Gear From Shaft

Inspect the inside diameter and thrust surfaces of the blower drive gear support for scoring and wear. Also check the outside diameter of the blower drive gear shaft for wear. The clearance between the shaft and the support should not be less than 0.0035 inch (with new parts) or more than 0.007 inch (with used parts).

Inspect the serrations on the blower drive shaft and, if worn so that excessive backlash is felt when the shaft is inserted into the blower drive gear shaft, install a new blower drive shaft.

Examine the blower drive support thrust washer for scoring and wear. Replace the thrust washer if necessary. The thickness of a new blower drive support thrust washer is 0 093 to 0 103 inch.

Inspect the gear teeth for evidence of scoring, pitting, burning, or wear. If necessary, install a new gear.

Assemble Blower Drive Support

Refer to Fig. 3 for the relative position of the parts and assemble the blower drive support as follows:

1. Lubricate the blower drive gear shaft with clean engine oil and insert the shaft into the blower drive support.

2. Assemble the thrust washer and the snapring on the shaft.

3. Install the key in the shaft, if it was removed.

4. Place the shaft and support in an arbor press.

5. Position the gear on the shaft so the keyway in the gear is in alignment with the key in the shaft. Then place a sleeve on the gear and press the gear on the shaft until the clearance between the gear and support is 0.004 to 0.006 inch (Fig. 4).

Instail Blower Drive Support

1. Affix a new blower drive support gasket to the cylinder block rear end plate.

2. Install the blower drive support assembly by reversing the removal procedure.

3. Tighten the 3/8-24 support-to-end plate bolts (with copper washers) and the 3/8-16 support-to-flywheel housing bolts (with plain washers and lockwashers) to 35 lb ft (47 Nm) torque.

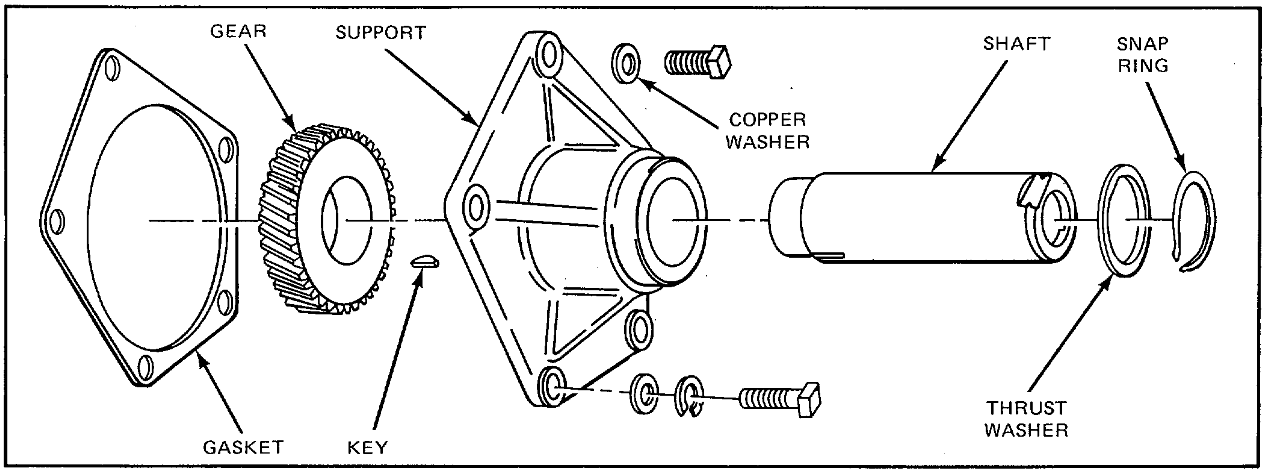


Figure 3. Blower Drive Gear and Support Assembly Details and Relative Location of Parts (In-Line Engine)

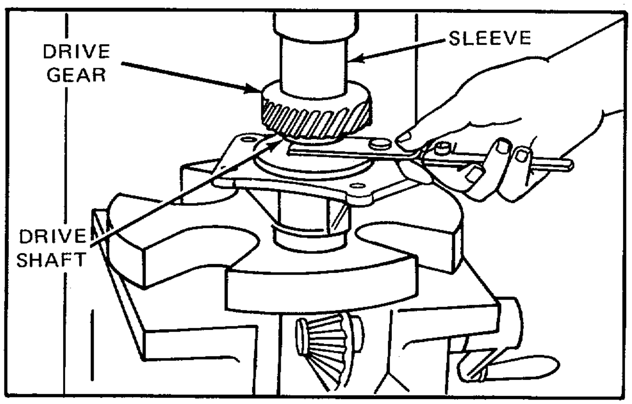


Figure 4. Pressing Blower Drive Gear On Shaft

ENGINE FRONT COVER (Upper)

The upper engine front cover is mounted against the cylinder block at the upper front end of the engine. The camshaft and balance shaft oil seals (in-line engine) or camshaft oil seals are pressed into the cover.

Remove Cover

When necessary, the oil seals may be removed without removing the upper front cover. This may be done by drilling diametrically opposite holes in the seal casing and threading metal screws, backed by flat washers, into the casing. Remove the seal by prying against the washers with pry bars. Install the new seals with installer J 9790.

If necessary, remove the engine cover as follows:

1. Remove the various parts and subassemblies from the engine as outlined in their respective sections of this manual.

2. Remove the pulleys from the front end of the camshaft and balance shaft. Refer to *Camshaft and Bearings.*

3. Remove the upper front cover-to cylinder block attaching bolts.

4. Tap the cover and dowel pin assembly away from the cylinder block.

5. Remove the woodruff keys and oil seal spacers from the shafts.

6. Remove all traces of the old gasket material from the cylinder block and cover.

Inspection

Check the oil seals and the spacers for wear or damage. Replace them. if necessary.

Remove Oil Seals

1. Support the inner face of the cover on woodblocks at least 1 inch thick to protect the dowel pins in the cover.

2. Drive the oil seals out of the cover.

Instail Oil Seals

1. Support the inner face of the cover on woodblocks.

2. If the outside diameter of the oil seal is not precoated with sealant, coat the bore in the cover with non-hardening sealant.

3. Position a new oil seal in the cover with the lip of the seal pointing toward the inner face of the cover.

CAUTION

Keep the lip of the oil seal clean and free from scratches.

4. Press the seal into the cover with installer J 9790 until the seal is flush with the bottom of the counterbore.

5. Install the second oil seal in the same manner.

6. Remove excess sealant from the cover and the seals.

Install Cover

1. Affix a new gasket to the cover.

2. Install the cover on the engine and secure it with bolts and lockwashers. Tighten the bolts to 35 lb ft (47 Nm) torque.

3. Apply cup grease to the outside diameter of the oil seal spacers, then slide them on the shafts.

NOTE

Current engines use an oil slinger between the oil seal spacer and the shoulder on the camshaft, and between the spacer and the end bearing on the balance shaft (in-line engine). Addition of the oil slinger improves sealing by reducing the amount of oil in the area of the oil seals.

If oil slingers are installed on inline engines built prior to serial number 4D-944, check the distance from the holes to the gasket flange (Fig. 1). If necessary, machine or grind the cover to provide sufficient clearance for the slingers.

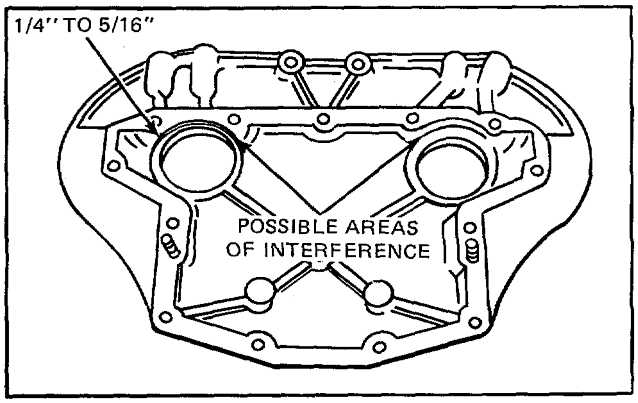


Figure 1. In-Line Engine Upper Front Cover

4. Install a woodruff key in each shaft.
5. Install the pulleys on the shafts.
6. Install and tighten the pulley retaining nuts to 300-325 lb ft (407-441 Nm) torque.

CYLIDER BLOCK
SHOP NOTES - TROUBLESHOOTING - SPECIFICATIONS - SERVICE TOOLS
SHOP NOTES
TEFLON-WRAPPED PIPE PLUGS

Pipe plugs with a baked teflon coating are available for service. However, pipe plugs can be hand wrapped satisfactorily with teflon tape to provide a better seal and facilitate plug removal. When a teflon-wrapped plug is installed, it is extremely important that the specified torque not be exceeded.

Hand wrap a pipe plug with teflon tape as follows:

1. Be sure the pipe plug is thoroughly clean and dry prior to applying the teflon tape. All dirt, grease, oil, and scale must be removed.

2. Start the tape one or two threads from the small or leading edge of the plug, joining the tape together with an overlap of approximately 1/8 inch.

3. Wrap the tape tightly in the same direction as you would turn a nut. The tape must conform to the configuration of the threads (be pressed into the minor diameter of the threads) without cutting or ripping the tape.

4. Hand tighten and hand torque the pipe plug and DO NOT exceed the specified torque. DO NOT use power tools.

CHECKING BEARING CLEARANCES

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic wire manufactured commercially and is available in three sizes and colors. Type PG-1 (green) has a clearance range of 0.001 to 0.003 inch, type PR-1 (red) has a range of 0.002 to 0.006 inch, and type PB-1 (blue) has a range of 0.004 to 0.009 inch.

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and crankshaft journal.

CAUTION

When checking the main bearing clearances with the engine in a position where the main bearing caps are supporting the weight of the crankshaft and the flywheel, an erroneous reading, due to the weight of the crankshaft and flywheel, can be eliminated by supporting the weight of the crankshaft with a jack under the counterweight adjoining the bearing being checked.

2. Place a piece of the plastic strip the full width of the bearing shell, about 1/4 inch off center (Fig. 1).

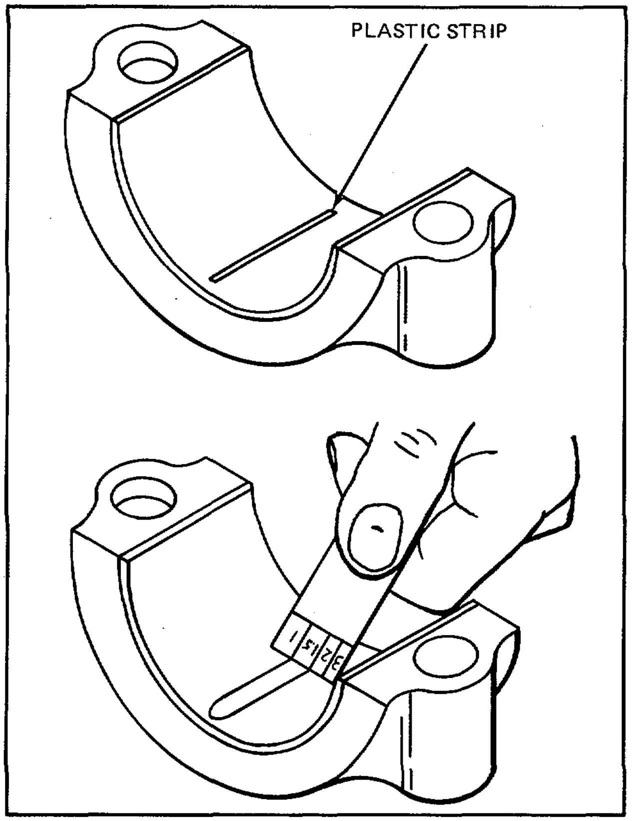


Figure 1. Using Plastic Strip to Measure Bearing-to-Crankshaft Clearance

3. Rotate the crankshaft about 30° from bottom dead center and reinstall the bearing cap. Tighten the bolts to the specified torque.

4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.

5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope (Fig. 1). The number within the graduation on the envelope indicates the bearing clearance in thousandths of an inch. Taper may be indicated when one end of the flattened plastic strip is wider than the other. Measure each end of the plastic; the difference between the readings is the approximate amount of taper.

CAMSHAFT CUP PLUG INSTALLATION

When an oil leak occurs at the drive plug area in the front end of the camshaft, install a cup plug in the end of the camshaft rather than removing and replacing the drive plug.

NOTE

It is not necessary to remove the camshaft from the engine when installing the cup plug.

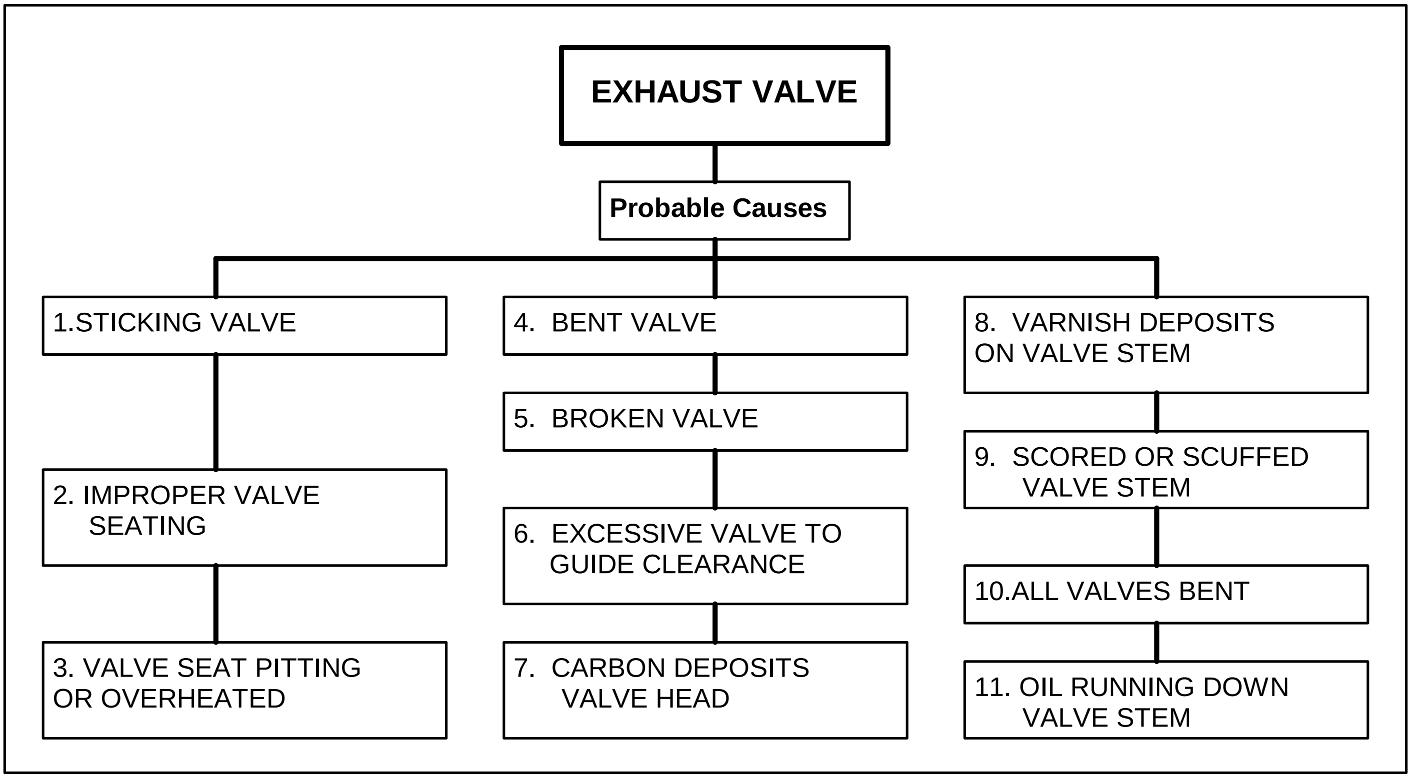
1. Clean the hole in the front end

of the camshaft and apply Permatex No.

Install the cup plug as follows:

1 sealant, or equivalent, to the outer diameter of the cup plug.

2. Install the plug to a depth of 0.180 to 0.210 inch with tool J 24094.


EXHAUST VALVE
Probable Causes
1.STICKING VALVE
2. IMPROPER VALVE SEATING
3. VALVE SEAT PITTING OR OVERHEATED
4. BENT VALVE
5. BROKEN VALVE
6. EXCESSIVE VALVE TO GUIDE CLEARANCE
7. CARBON DEPOSITS VALVE HEAD
8. VARNISH DEPOSITS ON VALVE STEM
9. SCORED OR SCUFFED VALVE STEM
10.ALL VALVES BENT
11. OIL RUNNING DOWN VALVE STEM

TROUBLESHOOTINM

SUGGESTED REMEDY

1. Check for carbon deposits, a bent valve guide, defective spring, or antifreeze (glycol) in the lubricating oil. Replace a bent guide. Clean up and reface the valve. Replace the valve if necessary.

2. Check for excessive valve-toguide clearance, bent valve guide, or carbon deposits. Replace a bent or worn guide. Clean the carbon from the valve. Reface or replace the valve, if necessary.

3. Check the operating conditions of the engine for overload, inadequate cooling, or improper timing. Reface the valve and insert. Replace the valve if it is warped or too badly pitted. Use a harder-face valve if operating conditions warrant.

4. Check for contact between the valve head and the piston as a result of incorrect valve clearance, an improperly positioned exhaust valve bridge (four-valve head), or a defective spring. Check the valve guide, insert, cylinder head, and piston for damage. Replace damaged parts.

5. Check for excessive valve-toguide clearance, defective valve spring or etching of the valve stem at the weld. Improper valve clearance is also a cause of this type of failure. Check the guide, insert, cylinder head, and piston for damage. Replace damaged parts.

6. Replace a worn valve guide. Check and replace the valve, if necessary.

7. Black carbon deposits extending from the valve seats to the guides indicates cold operation due to light loads or to the use of too heavy a fuel. Rusty brown valve heads with carbon deposits forming narrow collars near the guides indicate hot operation due to overloads, inadequate cooling, or improper timing which results in carbonization of the lubricating oil. Clean up the valves, guides, and inserts. Reface the valves and inserts or replace them if they are warped, pitted, or scored.

8. Check for worn valve guide or excessive exhaust back pressure. Replace a worn guide. Check the valve seat for improper seating. Reface the valve and insert or, if necessary, replace.

9. Check for a bent valve stem or guide,. metal chips or dirt, or for lack of lubrication. Clean up the valve stem with a crocus cloth wet with fuel oil or replace the valve. Replace the guide. When installing a valve, use care in depressing the spring so that the spring cap DOES NOT scrape the valve stem.

10. Check for a gear train failure or for improper gear train timing.

11. Check the operation of the engine for excessive idling and resultant low-engine exhaust back pressure. Install valve guide oil seals.

SPECIFICATIONS

Specifications, clearances, and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled Limits in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as limits must be qualified by the judgement of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES, AND WEAR LIMITS

These limits also apply to oversize and undersize parts

ENGINE PARTS (Standard Size, New)	MINIMUM (inch)	MAXIMUM (inch)	LIMITS (inch)
Cylinder Block			
Block bore:			
Diameter (top)	4.5195	4.5215	4.5235
Diameter (center)	4.4865	4.4880	4.4900
Diameter (bottom)	4.3565	4.3575	4.3595
Out-of -round		0.0015	0.0020
Taper		0.0015	0.0020
Cylinder liner counterbore:			
Diameter	4.8200	4.8350	
Depth	0.3000	0.3020	
Main bearing bore:			
Inside diameter	3.2510	3.2520	
Cam and balance shaft bore (oversize cam bearings):			
End	2.3850	2.3860	
Intermediate	2.3750	2.3760	
Center	2.3650	2.3660	
Top surface of block:			
Flatness--transverse (all)			0.0030
Flatness--longitudinal			0.0070
Depth of counterbores (top surface):			
Cylinder head seal strip groove	0.0970	0.1070	
Waterholes	0.1090	0.1150	
Oilholes	0.0920	0.0980	
Cylinder Liner			
Outside diameter (upper seal ring surface)	4.4850	4.4860	
Outside diameter (lower seal ring surface)	4.3550	4.3560	
Inside diameter	3.8752	3.8767	
Out-of-round (inside diameter		0.0020	0.0030
Taper (inside di ameter)		0.0010	0.0020

ENGINE PARTS (Standard Size, New)	MINIMUM (inch)	MAXIMUM (inch)	LIMITS (inch)
Depth of flange BELOW block	0.0465	0.0500	0.0500
Variation in depth between adjacent liners		0.0020	0.0020
Pistons and Rings			
Piston:			
Diameter (at skirt):			
Nonturbocharged engines	3.8699	3.8721	
Clearance--piston skirt-to-liner:			
Nonturbocharged engines	0.0031	0.0068	0.0100
Out-of-round		0.0005	
Taper		0.0005	
Inside diameter--piston pin bushing	1.3775	1.3780	
Compression rings:			
Gap (chrome ring)	0.0200	0.0460	0.0600
Gap (cast iron ring)	0.0200	0.0360	0.0600
Clearance--ring-to-groove:			
Top (No. 1)	0.0030	0.0060	0.0120
No. 2	0.0070	0.0100	0.0140
No. 3 and 4	0.0050	0.0080	0.0130
Oil control rings:			
Gap	0.0100	0.0250	0.0440
Clearance--ring-to-groove	0.0015	0.0055	0.0080
Piston Pins			
Diameter	1.3746	1.3750	
Clearance--pin-to-piston bushing	0.0025	0.0034	0.0100
Clearance--pin-to-conn. rod bushing	0.0010	0.0019	0.0100
Connecting Rod			
Length--center-to-center	8.7990	8.8010	
Inside diameter (upper bushing)	1.3760	1.3765	
Normal side clearance (in-line engine)	0.0030	0.0120	
Crankshaft			
Journal diameter--main bearing (in-line engine)	2.9990	3.0000	
Journal diameter--conn. rod bearing (in-line engine)	2.4990	2.5000	
Journal out-of-round		0.00025	0.0030
Journal taper		0.0005	0.0030

ENGINE PARTS (Standard Size, New)	MINIMUM (inch)	MAXIMUM (inch)	LIMITS (inch)
§Runout on journals--total indicator reading:			
Thrust washer thickness	0.1190	0.1220	
End play (end thrust clearance)	0.0040	0.0110	0.0180
Connecting Rod Bearing			
Inside diameter (vertical axis, in-line engine)	2.5015	2.5035	
Bearing-to-journal clearance (in-line engine)	0.0015	0.0045	0.0060
Bearing thickness 90° from parting line (in-line)	0.1245	0.1250	0.1230
Main Bearings			
Inside diameter (vertical axis, in-line engine)	3.0020	3.0030	
Bearing-to-journal clearance (in-line engine)	0.0010	0.0040	0.0060
Bearing thickness 90° from parting line (in-line engine)	0.1245	0.1250	0.1230
Camshaft			
Diameter (at bearing journals)	2.1820	2.1825	
Runout at center bearing (when mounted on end bearings)		0.0020	
End thrust	0.0050	0.0150	0.0190
Thrust washer thickness	0.2080	0.2100	
Balance Shaft			
Diameter (at bearing journals)	2.1820	2.1825	
End thrust	0.0050	0.0150	0.0190
Thrust washer thickness	0.2080	0.2100	
Camshaft and Balance Shaft Bearings			
Inside diameter	2.1870	2.1880	
Clearance--bearing-to-shaft	0.0045	0.0060	0.0080
Camshaft and Balance Shaft Gears			
Backlash	0.0030	0.0050	0.0070

§Runout tolerance given for guidance when regrinding crankshaft. Crankshaft for 4-53 supported on No. 1 and No. 5 journals; runout measured at No. 2, 3, and 4 journals.

When the runout on adjacent journals is in the opposite direction, the sum must not exceed 0.003 inch total indicator reading

When in the same direction, the difference must not exceed 0.003 inch total indicator reading. When high spots of runout on adjacent journals are at right angles to each other, the sum must not exceed 0.004 inch total indicator reading, or 0.002 inch on each journal.

ENGINE PARTS (Standard Size, New)	MINIMUM (inch)	MAXIMUM (inch)	LIMITS (inch)
Idler Gear			
Backlash	0.0030	0.0050	0.0070
Idler gear bearing inside diameter	2.1860	2.1870	
Idler gear hub outside diameter	2.1825	2.1835	
Clearance--bearing-to-hub	0.0025	0.0045	0.0070
End play	0.0060	0.0130	0.0170
Thrust washer thickness	0.1180	0.1200	
Crankshaft Timing Gear			
Backlash	0.0030	0.0050	0.0070
Inside diameter (gear)	4.0580	4.0590	
Outside diameter (crankshaft)	4.0600	4.0610	
Blower Drive Gear			
Backlash	0.0030	0.0050	0.0070
Thrust washer thickness	0.0930	0.1030	
End play (blower drive gear shaft)	0.0040	0.0060	
Governor Drive Gear			
Backlash	0.0030	0.0050	0.0070
Cylinder Head			
Cam follower bore (current)	1.0626	1.0636	
Cam follower bore (former)	1.0620	1.0630	
Exhaust valve insert counterbore:			
Diameter (4-valve head)	1.1590	1.1600	
Exhaust Valve Seat Inserts			
Outside diameter (4-valve)	1.1605	1.1615	
Seat width	0.0468	0.0781	0.0781
Valve seat runout		0.00020	0.0020
Exhaust Valves			
Stem diameter (current 4-valve)	0.2480	0.2488	
Stem diameter (former 4-valve)	0.2475	0.2485	
Valve head-to-cylinder head:			
Current 4-valve headflush	flush	0.024 recess.	0.039 recess.
Former 4-valve head	0.006 protr.	0.018 recess.	0.033 recess.

ENGINE PARTS (Standard Size, New)	MINIMUM (inch)	MAXIMUM (inch)	LIMITS (inch)
Valve Guides			
Distance below top of head (plain guide)...	0.0100	0.0400	
Distance below top of head (machined for seal)................................	0.1900	0.2200	
Diameter--inside (4-valve)	0.2505	0.2515	
Clearance--Valve-to-guide (current 4-valve)	0.0017	0.0035	0.0050
Clearance--Valve-to-guide (former 4-valve).......................................	0.0020	0.0040	0.0050
Rocker Arms and Shafts			
Diameter--rocker shaft..	0.8735	0.8740	
Diameter--inside (rocker arm bushing)...	0.8750	0.8760	
Diameter--inside (valve rocker arm bore)...	0.8753	0.8763	
Clearance--shaft-to-injector rocker bushing.......................................	0.0010	0.0025	0.0040
Clearance--shaft-to-valve rocker bore..	0.0013	0.0028	0.0040
Can Followers			
Diameter *	1.0600	1.0610	
Clearance--follower-to-current head...	0.0016	0.0036	0.0060
Clearance--follower-to-former head	0.0010	0.0030	0.0060
Rollers and pins:			
Clearance--pin-to-bushing..	0.0013	0.0021	0.010 horiz.
Side clearance--roller-to-follower	0.0110	0.0230	0.0230

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb ft)	(Nm)	THREAD SIZE	280M OR BETTER TORQUE (lb ft)	(Nm)
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	810	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolthead	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM-260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM-275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	BM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

BOLT IDENTIFICATION CHART

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Cam follower guide bolts	1/4-20	12-15	16-20
Idler gear bearing retaining bolts (8V)	1/4-20	12-15	16-20
Injector control shaft bracket bolts	1/4-28	10-12	14-16
Governor to flywheel housing bolts	5/16-18	10-12	14-16
Idler gear hub and spacer bolts	5/16-18	19-23	26-31
Oil pan bolts	5/16-18	10-20	14-27
Air box cover bolts	3/8-16	12-16	16-22
Flywheel housing bolts	3/8-16	25-30	34-41
Idler gear hub and spacer bolts	3/8-16	40-45	54-61
Injector clamp bolts	3/8-16	20-25	27-34
Connecting rod nuts	3/8-24	40-45	54-61
Flywheel housing bolts	3/8-24	25-30	34-41
Fuel connector	3/8-24	20-28	27-38
Fuel line nuts	3/8-24	12-15	16-20
Rocker arm bracket bolts	7/16-14	50-55	68-75
*Flywheel bolts (see Flywheel)	1/2-20		
*Main bearing cap bolts	9/16-12	120-130	163-177
*Flywheel bolts (8V) (see Flywheel)	9/16-12		
*Cylinder head bolts	5/8-11	170-180	231-244
Accessory drive pulley retaining nut	3/4-16	120-140	163-190
Air compressor drive pulley nut	3/4-16	80-100	108-136
Crankshaft end bolt (in-line and 6V engine)	3/4-16	290-300	393-407
Flange mounted air compressor drive shaft nut	3/4-10	§	§
Crankshaft end bolt (engines with cone-mounted pulley stamped with letter A)	1-14	200-220	271-298
Camshaft and balance shaft nut	1-1/8-18	300-325	407-441

*Lubricate at assembly with International Compound No. 2, or equivalent (refer to parts catalog).

§100 lb ft (136 Nm) plus increase torque to line-up cotter pin.

STANDARD PIPE PLUG TORQUE SPECIFICATIONS

Use sealing compound on plugs without gaskets or teflon.

NPTF SIZE THREAD	TORQUE (lb ft)	TORQUE (Nm)	NPTF SIZE THREAD	TORQUE (lb ft)	TORQUE (Nm)
1/8	10-12	14-16	3/4	33-37	45-50
1/4	14-16	19-22	1	75-85	102-115
3/8	18-22	24-30	1-1/4	95-105	129-143
1/2	23-27	31-37	1-1/2	110-130	150-177

SERVICE TOOLS

TOOL NAME	TOOL NO.
Cylinder Block	
Bore gage	J 5347-01
Dial bore gage master setting fixture	J 23059-01
Dial indicator set	J 22273
Engine overhaul stand	J 6837-01
Adaptor plate (in-line)	J 7622-01
Cylinder Head	
Injector body brush	J 8152
Cam follower holding fixture	J 5840-01
Cylinder head guides (set of 2)	J 9665
Cylinder head lifter	J 22062-01
Dial gage (2 and 4-valve head)	J 8165-2
Grinder (2 and 4-valve head)	J 8165-1
Piston ring gap feeler gage set	J 3172
Push rod remover (set of three)	J 3092-01
Socket	J 8932-01
Spring tester	J 22738-02
Valve guide cleaner	J 7793
Valve guide installer (15° 4-valve head)	J 7832
Valve guide installer (45° 4-valve head)	J 9729
Valve guide installer (machined for seal)	J 24519
Valve guide installer (guide used with oil seal)	J 9730
Valve guide oil seal installer	J 29579
Valve guide remover	J 7775
Valve seat grinder adaptor kit	J 7792-01
Valve seat insert installer	J 7790
Valve seat insert remover	J 7774
Valve seat insert remover	J 23479-15
Valve seat insert remover collet	J 23479-8
Valve spring checking gage	J 25076-01
Valve spring compressor	J 7455
Crankshaft	
Crankshaft front oil seal installer	J 22153
Crankshaft front oil seal sleeve installer	J 22524
Crankshaft pulley installer	J 7773
Crankshaft pulley remover	J 5356
Crankshaft rear oil seal (O.S.) expander	J 21278-01
Crankshaft rear oil seal sleeve installer	J 21277
Crankshaft timing gear remover	J 4871
Handle	J 3154-1
Micrometer ball attachment	J 4757
Oil seal expander	J 9769
Oil seal expander (in-line and 6V)	J 7454

TOOL NAME	TOOL NO.
Oil seal installer	J 9479
Oil seal installer	J 9727
Oil seal installer	J 9783
Puller	J 24420

Flywheel

Flywheel lifting fixture	J 25026
Flywheel lifting tool	J 6361-01
Remover and replacer set	J 3154-04
Slide hammer puller set	J 5901-01

Flywheel Housing

Crankshaft rear oil seal expander (O.S. seal)	J 21278-01
Crankshaft rear oil seal expander (Std. size seal)	J 9769
Dial indicator	J 8001-3
Dial indicator post	J 9748
Flywheel housing aligning studs (set of 2)	J 7540
Flywheel housing concentricity gage	J 9737-01

Piston, Connecting Rod, and Cylinder Liner

Bore gage	J 5347-01
Connecting rod bushing reamer set	J 7608-02
Connecting rod holder	J 7632
Cylinder hone set (2 1/2 to 5 3/4 inch range)	J 5902-01
Cylinder liner remover set	J 22490
Dial bore gage master setting fixture	J 23059-01
Dial indicator set	J 22273
Holddown clamp	J 21793-01
Master ring-cylinder liner	J 8385-01
Micrometer ball attachment	J 4757
Piston and connecting rod bushing installer and remover set	J 1513-02
Piston bushing reamer set	J 4970-02
Piston bushing reaming fixture	J 5273
Piston and connecting rod bushing installer and remover set	J 7587
Piston pin retainer installer	J 23762
Piston pin retainer leak detector	J 23987
Piston ring compressor	J 6883-01
Piston ring remover and in staller	J 8128
Piston-to-liner feeler gage set	J 5438-01
Spray nozzle remover	J 8995

Camshaft

Bar-type puller	J 24420
Camshaft and balance shaft bearing remover and installer set	J 7593-03
Camshaft cup plug installer	J 24094
Camshaft oil seal installer	J 21899

TOOL NAME	TOOL NO.
Crankshaft timing gear installer	J 7557
Slide hammer	J 6471-02
Spring scale	J 8129
Upper front cover seal installer	J 9790

FUEL SYSTEM

The fuel system (Fig. 1) includes the fuel injectors, fuel pipes (inlet and outlet), fuel manifolds (integral with the cylinder head), fuel pump, fuel strainer, fuel filter, and fuel lines.

Fuel is drawn from the supply tank through the fuel strainer and enters the fuel pump at the inlet side. Leaving the pump under pressure, the fuel is forced through the fuel filter and into the inlet fuel manifold, then through fuel pipes into the inlet side of each injector.

The fuel manifolds are identified by the words IN (top passage) and OUT (bottom passage), which are cast in several places in the side of the cylinder head. This aids installation of the fuel lines.

Surplus fuel returns from the outlet side of the injectors to the fuel manifold and then back to the supply tank.

All engines are equipped with a restrictive fitting in the fuel outlet manifold to maintain fuel system pressure. Refer to *Crankshaft Oil Seals* for the size fitting required.

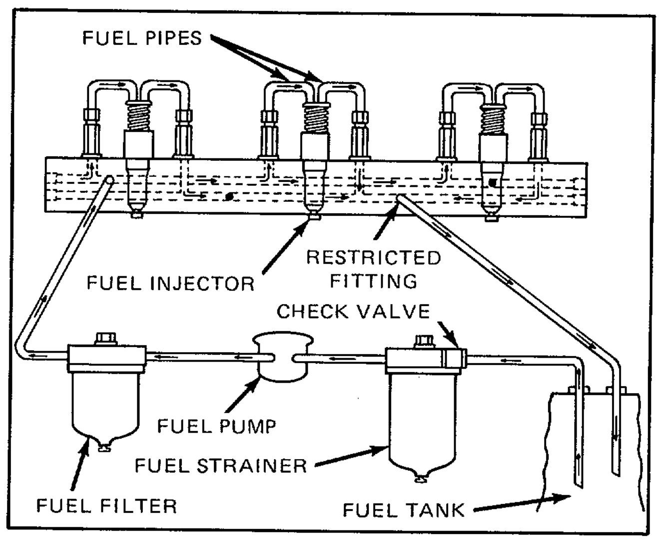


Figure 1. Typical Fuel System for In-Line Engines

A check valve may be installed in the supply line between the fuel tank and the fuel strainer to prevent fuel from draining back when the engine is shut down.

FUEL INJECTOR

The fuel injector (Fig. 1 and 2) is a lightweight, compact unit which enables quick, easy starting directly on diesel fuel and permits the use of a simple, open-type combustion chamber. The simplicity of design and operation provides for simplified controls and easy adjustment. No high-pressure fuel lines or complicated air-fuel mixing or vaporizing devices are required.

The fuel injector performs the following four functions:

1. Creates the high fuel pressure required for efficient injection.

2. Meters and injects the exact amount of fuel required to handle the load.

3. Atomizes the fuel for mixing with the air in the combustion chamber.

4. Permits continuous fuel flow. Combustion required for satisfactory engine operation is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder.

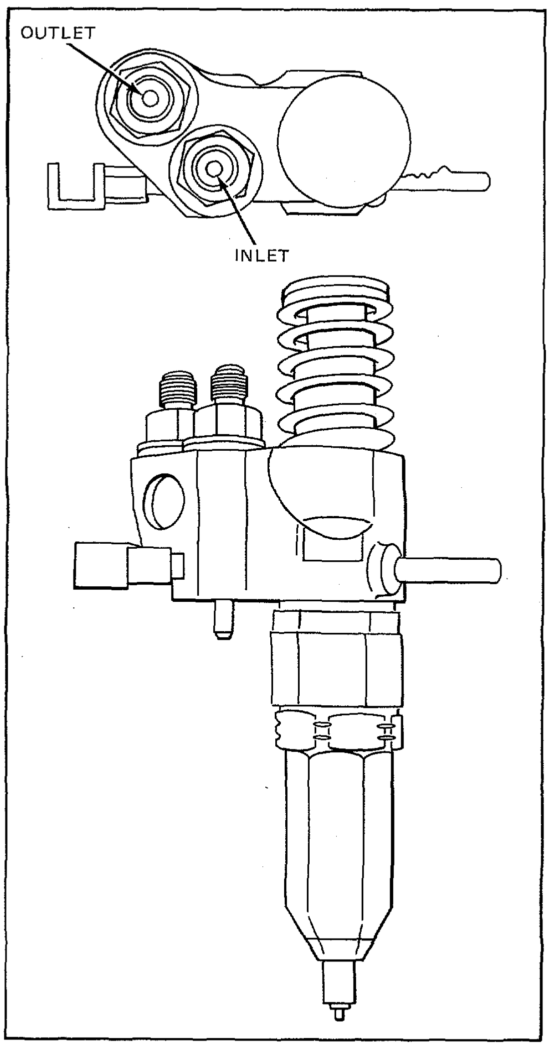


Figure 1. Fuel Injector Assembly.

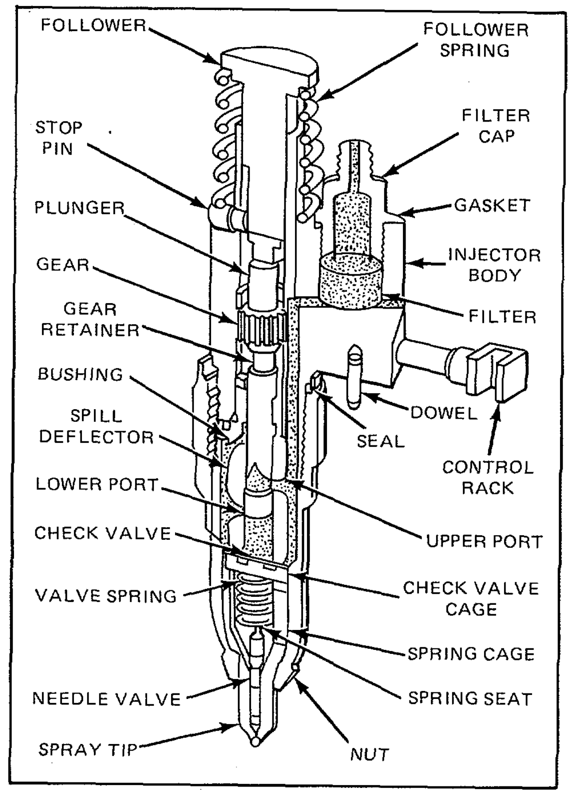


Figure 2. Cutaway View of Fuel Injector

Metering of the fuel is accomplished by an upper and lower helix machined in the lower end of the injector plunger. Figure 3 illustrates the fuel metering from no load to full load by rotation of the plunger in the bushing.

Figure 4 illustrates the phases of injector operation by the vertical travel of the injector plunger.

The continuous fuel flow through the injector serves, in addition to preventing air pockets in the fuel system, as a coolant for those injector parts subjected to high combustion temperatures.

To vary the power output of the engine, injectors having different fuel output capacities are used. The fuel output of the various injectors is governed by the helix angle of the plunger and the type of spray tip used. Refer to Fig. 5 for the identification of the injectors and their respective plungers and spray tips.

Since the helix angle on the plunger determines the output and operating characteristics of a particular type of injector, it is imperative that the correct injectors are used for each engine application. If injectors of different types are mixed, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers.

CAUTION

Do not intermix the needle valve injectors with other types of injectors in an engine.

Each fuel injector has a circular disc pressed into a recess at the front side of the injector body for identification purposes (Fig. 5). The identification tag indicates the nominal output of the injector in cubic millimeters.

Each injector control rack (Fig. 2) is actuated by a lever on the injector control tube which, in turn, is connected to the governor by means of a fuel rod. These levers can be adjusted independently on the control tube, thus permitting a uniform setting of all injector racks.

The fuel injector combines, in a single unit, all the parts necessary to provide complete and independent fuel injection at each cylinder.

Operation

Fuel, under pressure, enters the injector at the inlet side through a filter cap and filter (Fig. 2). From the

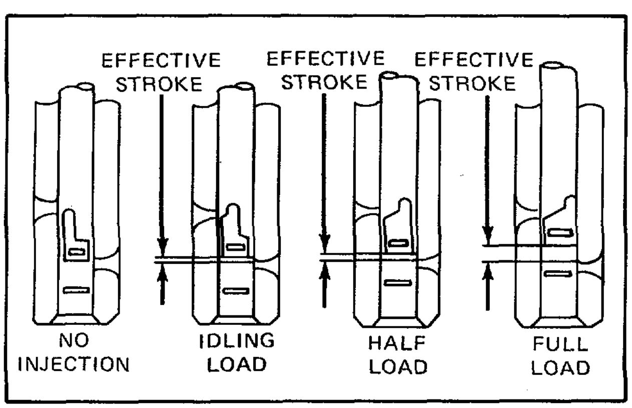


Figure 3. Fuel Metering from No Load to Full Load.

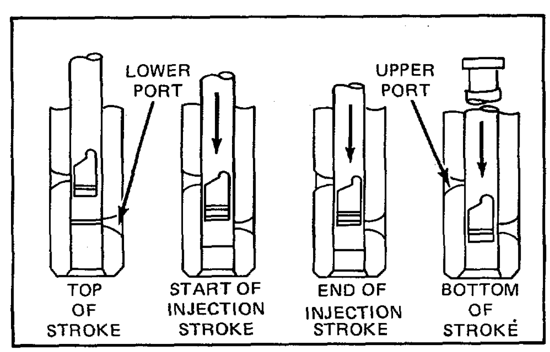
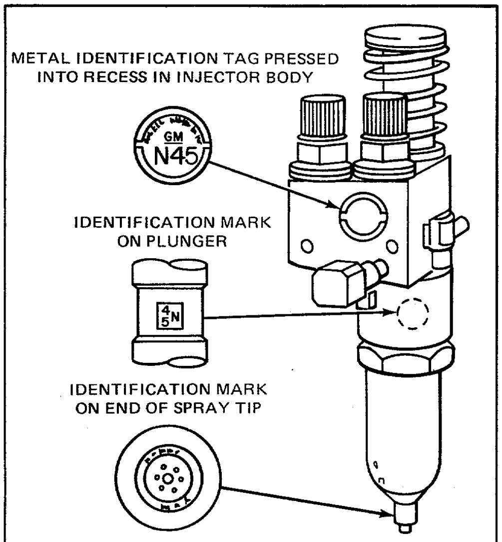


Figure 4. Phases of Injector Operation Through Vertical Travel of Plunger

filter, the fuel passes through a drilled passage into the supply chamber (that area between the plunger bushing and the spill deflector, in addition to that area under the injector plunger within the bushing). The plunger operates up and down in the bushing, the bore of which is open to the fuel supply in the annular chamber by two funnel-shaped ports in the plunger bushing.

The motion of the injector rocker arm is transmitted to the plunger by the follower which bears against the follower spring (Fig. 6). In addition to the reciprocating motion, the plunger can be rotated, during operation, around its axis by the gear which meshes with the control rack. For metering the fuel, an upper helix and a lower helix are machined in the lower part of the plunger. The relation of the helices to the two ports changes with the rotation of the plunger.

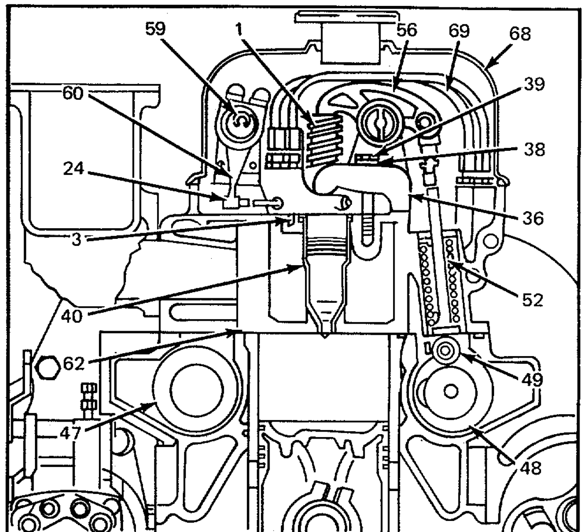
As the plunger moves downward under pressure of the injector rocker arm, a portion of that fuel trapped under the plunger is displaced into the supply



INJECTOR	SPRAY TIP*	PLUNGER
N35	6 – .006 – 165A	N35
L40	8 – .0055 – 165A	4L
N40	6 – .006 – 165A	4N
N45	6 – .006 – 165A	45N
N50	6 – .006 – 165A	5N
C40	6 – .006 – 165A	4C
C45	6 – .006 – 165A	45C
C50	6 – .006 – 165A	5C
5A50	8 – .0060 – 165A	5A50
5A55	8 – .0060 – 165A	5A55
5A60	8 – .0060 – 165A	6N
N55	8 – .0055 – 165A	55N
N60	8 – .0055 – 165A	6N
N65	8 – .006 – 165A	65N
5N65	7 – .006 – 165A	55N
N70	7 – .006 – 165	7N
M60	7 – .006 – 165	5N
M70	7 – .0060 – 165A	M70

* FIRST NUMERAL INDICATES NUMBER OF SPRAY HOLES, FOLLOWED BY SIZE OF HOLES AND ANGLE FORMED BY SPRAY FROM HOLES.

Figure 5. Injector Identification Chart.



1.	Injector Assembly	49.	Cam Follwer Assy.
3.	Pin--Dowel	52.	Rod--Push
24.	Rack--Injector Control	56.	Arm--Injector Rocker
36.	Clamp--Injector	59.	Tube--Injector Control
38.	Washer	60.	Lever--Rack Control
39.	Bolt	62.	Head--Cylinder
40.	Tube--Injector Hole	68.	Pipe--Fuel Inlet (Supply)
47.	Shaft--Balance	69.	Pipe--Fuel Outlet (Return)
48.	Camshaft		

Figure 6. Fuel Injector Mounting.

chamber through the lower port until the port is closed off by the lower end of the plunger. A portion of the fuel trapped below the plunger is then forced up through a central passage in the plunger, into the fuel metering recess, and into the supply chamber through the upper port until that port is closed off by the upper helix of the plunger. With the upper and lower ports both closed off, the remaining fuel under the plunger is subjected to increased pressure by the continued downward movement of the plunger.

When sufficient pressure is built up, it opens the flat, nonreturn check valve. The fuel in the check valve cage, spring cage, tip passages, and tip fuel cavity is compressed until the pressure force acting upward on the needle valve is sufficient to open the valve against the downward force of the valve spring. As soon as the needle valve lifts off of its seat, the fuel is forced through the small orifices in the spray tip and atomized into the combustion chamber.

When the lower land of the plunger uncovers the lower port in the bushing, the fuel pressure below the plunger is relieved and the valve spring closes the needle valve, ending injection.

A pressure relief passage has been provided in the spring cage to permit bleed-off of fuel leaking past the needle pilot in the tip assembly.

A check valve, directly below the bushing, prevents leakage from the combustion chamber into the fuel injector in case the valve is accidentally held open by a small particle of dirt. The injector plunger is then returned to its original position by the injector follower spring. Figure 4 shows the various phases of injector operation by the vertical travel of the injector plunger.

On the return upward movement of the plunger, the high-pressure cylinder within the bushing is again filled with fuel oil through the ports. The constant circulation of fresh cool fuel through the injector renews the fuel supply in the chamber, helps cool the injector, and also effectively removes all traces of air which might otherwise accumulate in the system and interfere with accurate metering of the fuel.

The fuel injector outlet opening, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, is directly adjacent to the inlet opening.

Changing the position of the helices, by rotating the plunger, retards or advances the closing of the ports and the beginning and ending of the injection period. At the same time, it increases or decreases the amount of fuel injected into the cylinder. Figure 3 shows the various plunger positions from no load to full load. With the control rack pulled out all the way (no injection), the upper port is not closed by the helix until after the lower port is uncovered. Consequently, with the rack in this position, all of the fuel is forced back into the supply chamber and no injection of fuel takes place. With the control rack pushed all the way in (full injection), the upper port is closed shortly after the lower port has been covered, thus producing a maximum effective stroke and maximum injection. From this no-injection position to full-injection position (full-rack movement), the contour of the upper helix advances the closing of the ports and the beginning of injection.

General Instructions for Injector Care and Overhaul

The fuel injector is one of the most important and precisely-built parts of the engine. The injection of the correct amount of fuel into the combustion chamber at exactly the right time depends upon this unit. Because the injector operates against high-compression pressure in the combustion chamber, efficient operation demands that the injector assembly is maintained in first-class condition at all times. Proper maintenance of the fuel system and the use of the recommended type fuel filters and clean water-free fuel are the keys to trouble-free operation of the injectors.

Due to the close tolerances of various injector parts, extreme cleanliness and strict adherence to service instructions is required.

Perform all injector repairs in a clean, well-lighted room with a dust- free atmosphere. An ideal injector room is slightly pressurized by means of an electric fan which draws air into the room through a filter. This pressure prevents particles of dirt and dust from entering the room through the doors and windows. A suitable air outlet will remove solvent fumes along with the outgoing air. Also, provide a source for 110-volt alternating current electric power.

Provide the injector repair room with a supply of filtered, moisture-proof compressed air for drying the injector parts after they have been cleaned. Use wash pans of rustproof material and deep enough to permit all of the injector parts to be completely covered by the cleaning agent, usually clean fuel oil, when submerged in wire baskets of 16-mesh wire screen. Use baskets that will support the parts so as to avoid contact with the dirt which settles at the bottom of the pans.

Rags should never be used for cleaning injector parts since lint or other particles will clog parts of the injector when it is assembled. A lint-free cleaning tissue is a good, inexpensive material for wiping injector parts.

When servicing an injector, follow the general instructions outlined below:

1. Whenever the fuel pipes are removed from an injector, cover the filter caps with shipping caps to keep dirt out of the injectors. Also protect the fuel pipes and fuel connectors from the entry of dirt or other foreign material.

2. After an injector has been operated in an engine, do not remove the filter caps or filters while the injector is in the engine. Replace the filters only at the time of complete disassembly and assembly of an injector.

NOTE

In the offset injector, a filter is used in the inlet side only. No filter is required on the outlet side (Fig. 35).

3. Whenever an injector has been removed and reinstalled or replaced in an engine, make the following adjustments as outlined in *Engine Tuneup*.

a. Time the injector.

b. Position the injector control rack.

4. Whenever the engine is to be out of service for an extended period, purge the fuel system, then fill it with a good grade of rust preventive (refer to *Storage*).

5. When a reconditioned injector is to be placed in stock, fill it with injector test oil J 26400. DO NOT use fuel oil. Install shipping caps on both filter caps immediately after filling. Store the injector in an upright position to prevent test oil leakage.

CAUTION

Make sure that new filters have been installed in a reconditioned injector which is to be placed in stock. This precaution will prevent dirt particles from entering the injector due to a possible reversal of fuel flow when installing the injector in an engine other than the original unit.

Remove Injector

1. Clean and remove the valve rocker cover.

2. Remove the fuel pipes from both the injector and the fuel connectors (Fig. 6).

CAUTION

Immediately after removal of the fuel pipes from an injector, cover the filter caps with shipping caps to prevent dirt from entering the injector. Also protect the fuel pipes and fuel connectors from entry of dirt or foreign material.

3. Crank the engine to bring the outer ends of the push rods of the injector and valve rocker arms in line horizontally.

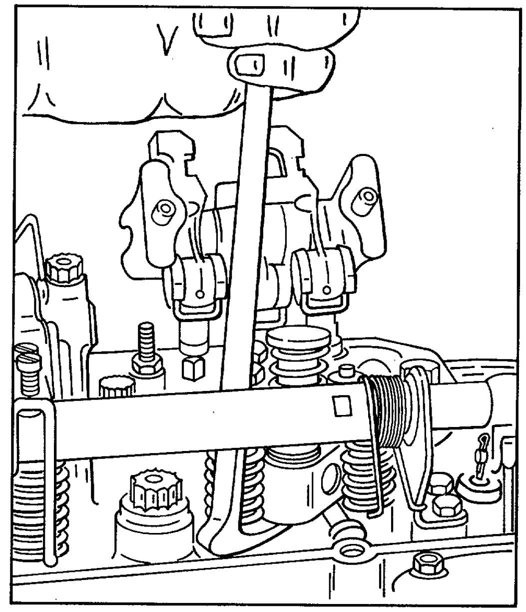


Figure 7. Removing Injector from Cylinder Head.

4. Remove the two rocker shaft bracket bolts and swing the rocker arms away from the injector and valves (Fig. 7).

5. Remove the injector clamp bolt, special washer, and clamp.

6. Loosen the inner and outer adjusting screws (certain engines have only one adjusting screw and locknut) on the injector rack control lever and slide the lever away from the injector.

7. Lift the injector from its seat in the cylinder head.

8. Cover the injector hole in the cylinder head to keep foreign material out.

9. Clean the exterior of the injector with clean fuel oil and dry it with compressed air.

TEST INJECTOR

WARNING

The fuel spray from an injector can penetrate the skin. Fuel oil which enters the blood-stream can cause a serious infection. Therefore, follow instructions and use the proper equipment to test an injector.

If inspection does not reveal any external damage, perform a series of tests to determine the condition of the injector to avoid unnecessary overhauling. Tests must be performed using injector test oil J 26400.

An injector that passes all of the tests outlined below may be considered to be satisfactory for service without disassembly, except for the visual check of the plunger.

However, an injector that fails to pass one or more of the tests is unsatisfactory. Perform all of the tests before disassembling an injector to correct any one condition.

Identify each injector and record the pressure drop and fuel output as indicated by the following tests.

Injector Control Rack and Plunger Movement Test

Place the injector in the injector fixture and rack freeness tester J 22396. Refer to Fig. 8 and place the handle on top of the injector follower.

If necessary, adjust the contact screw in the handle to ensure the contact screw is at the center of the follower when the follower spring is compressed.

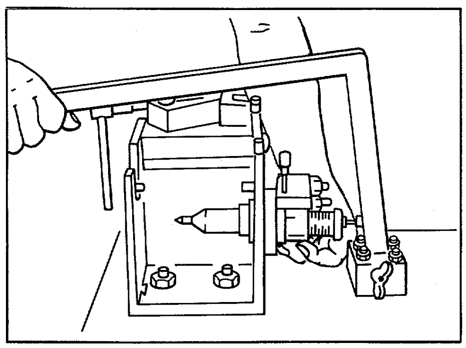


Figure 8. Checking Rack and Plunger for Free Movement with J 22396

With the injector control rack held in the no-fuel position, push the handle down and depress the follower to the bottom of its stroke. Then very slowly release the pressure on the handle while moving the control rack up and down as shown in Fig. 8 until the follower reaches the top of its travel. If the rack does not fall freely, loosen the injector nut, turn the tip, then retighten the nut. Loosen and retighten the nut a couple of times if necessary. Generally this will free the rack. Then, if the rack isn't free, change the injector nut. In some cases it may be necessary to disassemble the injector to eliminate the cause of the misaligned parts.

Visual Inspection of Plunger

An injector which passes all of the previous tests should have the plunger checked visually, under a magnifying glass, for excessive wear or a possible chip on the bottom helix. There is a small area on the bottom helix and lower portion of the upper helix that, if chipped, will not be indicated in any of the tests.

Remove the plunger from the injector as follows:

1. Support the injector, right side up, in holding fixture J 22396.

2. Compress the follower spring. Then raise the spring above the stop pin with a screwdriver and withdraw the pin (Fig. 9). Allow the spring to rise gradually.

3. Remove the injector from the holding fixture. Turn the injector upside down, to prevent the entry of dirt, and catch the spring and plunger as they drop out.

4. Inspect the plunger. If the plunger is chipped (Fig. 10), replace the plunger and bushing assembly.

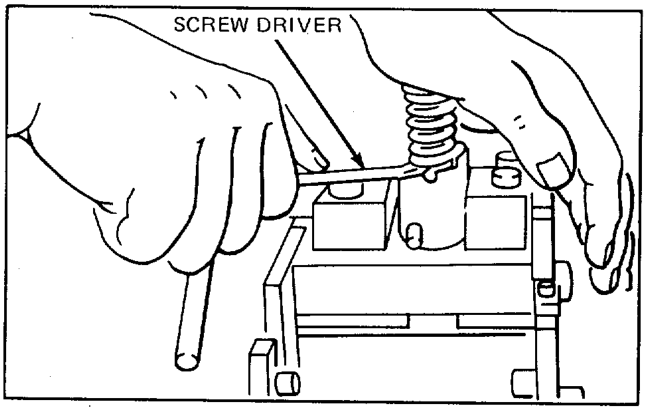


Figure 10. Unusable Injector Plungers

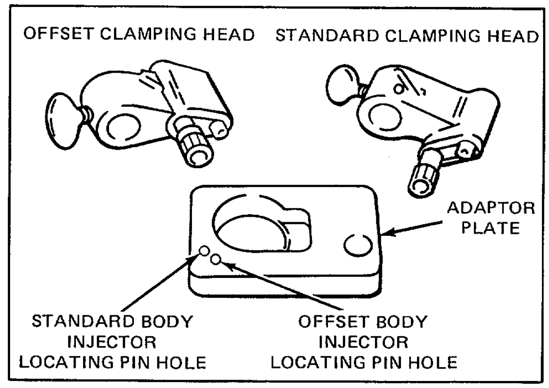


Figure 11. Injector Tester J23010 Clamping Heads

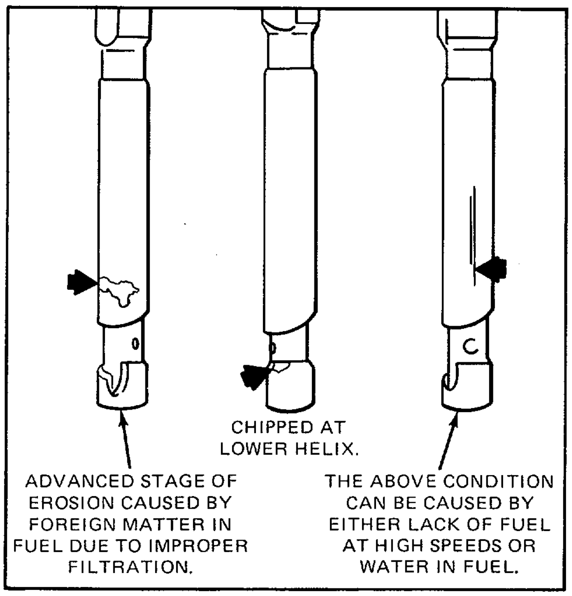


Figure 10. Unusable Injector Plungers

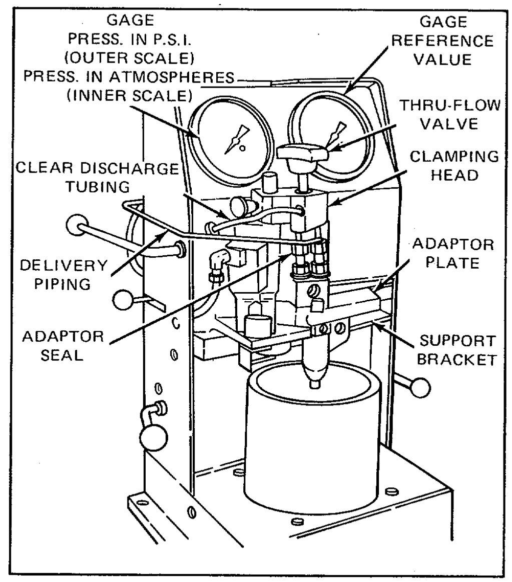


Figure 12. Injector Installed in Tester J23010 with Clamping Head

5. Reinstall the plunger, follower, and spring.

Installing Fuel Injector in Tester J 23010

1. Select the proper clamping head (Fig. 11). Position it on the clamping, post and tighten the thumbscrew into the lower detent position (Fig. 12).

2. Connect the test oil delivery piping into the clamping head.

3. Connect the test oil, clear discharge tubing onto the pipe on the clamping head.

4. Locate the adaptor plate on top of the support bracket by positioning the 3/8-inch diameter hole at the far right of the adaptor plate onto the 3/8-inch diameter dowel pin. This allows the adaptor plate to swing out for mounting the fuel injector.

5. Mount the injector through the large hole and insert the injector pin in the proper locating pinhole (Fig. 11).

6. Swing the mounted injector and adaptor plate inward until they contact the stop pin at the rear of the support bracket.

Clamping the Fuel Injector

1. Refer to Fig. 13 and position the injector tester levers as follows:

   a. Lever 2 up and to the rear

   b. Lever 3 in the rear detent

   c. Lever 4 up (horizontal)

   d. Lever 5 up (horizontal)

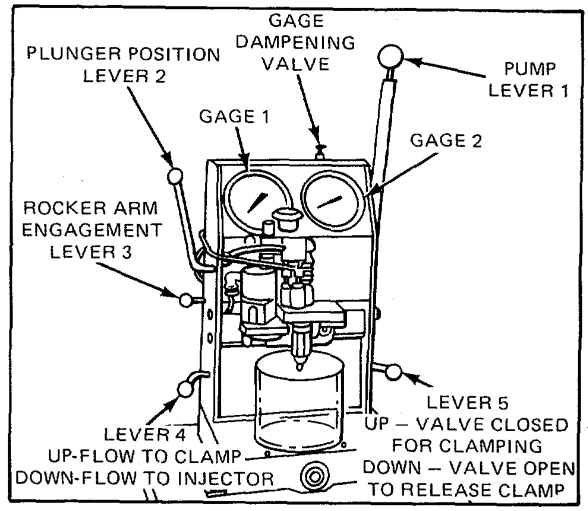


Figure 13. Injector in Position for Testing with Tester J 23010

2. Align the clamping head nylon seals over the injector filter caps (Fig. 12).

3. Back off the thru-flow valve about halfway to allow the self-aligning nylon seals to seat properly during the clamping operation.

4. Hold the clamping head in position over the filter caps and, with the left hand, operate pump lever 1 evenly to move the clamping head down to seal the filter caps.

NOTE

The thru-flow valve should still turn freely. If it does not, turn the valve counter-clockwise until it rotates freely and reapply clamping pressure.

CAUTION

Excessive force on lever 1 during clamping can damage the seals in the valves operated by levers 4 and 5.

Purging Air from the System

Move lever 4 down and operate pump lever 1 to produce a test oil flow through the injector. When air bubbles no longer pass through the clear discharge tubing, the system is free of air and is now ready for testing.

Injector Valve Opening and Spray Pattern Test

This test determines spray pattern uniformity and the relative pressure at which the injector valve opens and fuel injection begins.

1. Clamp the injector properly and purge the air from the system.

2. Move lever 4 down.

3. Position the injector rack in the full-fuel position.

4. Place pump lever 1 in the vertical position.

5. Move lever 3 to the forward detent position.

6. The injector follower should be depressed rapidly (at 40 to 80 strokes-per-minute) to simulate operation in the engine. Observe the spray pattern to see that all spray orifices are open and dispersing the test oil evenly. The beginning and ending of injection should be sharp and the test oil should be finely atomized with no drops of test oil forming on the end of the tip.

The highest pressure reference number shown on gage 2 will be reached just before injection ends. Use the following reference values to determine the relative acceptability of the injector. Reference values for Series 53 injectors are from 127 minimum to 146 maximum, except the L-40 injector which is from 116 minimum to 127 maximum.

NOTE

The reference value obtained when pop testing the needle valve injectors is to be used as a troubleshooting and diagnosis aid. This allows comparative testing of injectors without disassembly. Exact valve opening pressure values can only be determined by the *Needle Valve Tip Test* using tester J 23010 and tip test adaptor J 23010-129, or auxiliary tester J 22640.

Injector High-Pressure Test

This test checks for leaks at the filter cap gaskets, body plugs, and nut seal ring.

1. Clamp the injector properly and purge the air from the system.

2. Close the thru-flow valve, but do not overtighten.

NOTE

Make sure lever 4 is in the down position before operating pump lever 1.

3. Operate pump lever 1 to build up to 1600 to 2000 psi (11 024 to 13 780 kPa) on gage 1. Check for leakage at the injector filter cap gaskets, body plugs, and injector nut seal ring.

Injector Pressure Holding Test

This test determines if the body-to-bushing mating surfaces in the injector are sealing properly and indicates proper plunger-to-bushing fit.

1. Clamp the injector properly and purge the air from the system.
2. Close the thru-flow valve, but do not overtighten.
3. Move lever 2 to the rear, horizontal position.
4. Operate pump lever 1 until gage 1 reads approximately 700 psi (4 823 kPa).
5. Move lever 4 to the up position.
6. Time the pressure drop between 450 to 250 psi (3 100 to 1 723 kPa). If the pressure drop occurs in less than 15 seconds, leakage is excessive.

Refer to the *Troubleshooting Charts* if the fuel injector does not pass any of the preceding tests.

If the fuel injector passes all of the above tests, proceed with the Fuel Output Test.

Unclamping the Injector

1. Open the thru-flow valve to release pressure in the system.

2. Move lever 5 down to release the clamping pressure.

3. Swing out the adaptor plate and remove the injector after the nylon seals in the clamping head are free and clear of the injector filter caps.

4. Carefully return lever 5 to the up (horizontal) position.

Needle Valve Tip Test (Using J 23010 Tester and Tip-Test Adaptor)

Assemble injector parts on tip-test adaptor as follows:

1. Clamp the flat sides of tip-test adaptor J 23010-129 firmly in a vise and assemble the cleaned injector parts including the check valve cage, spring, spring seat, spring cage, and spray tip assembly.

2. Carefully pilot the injector nut over the spray tip and valve parts and thread it onto the adaptor (Fig. 14).

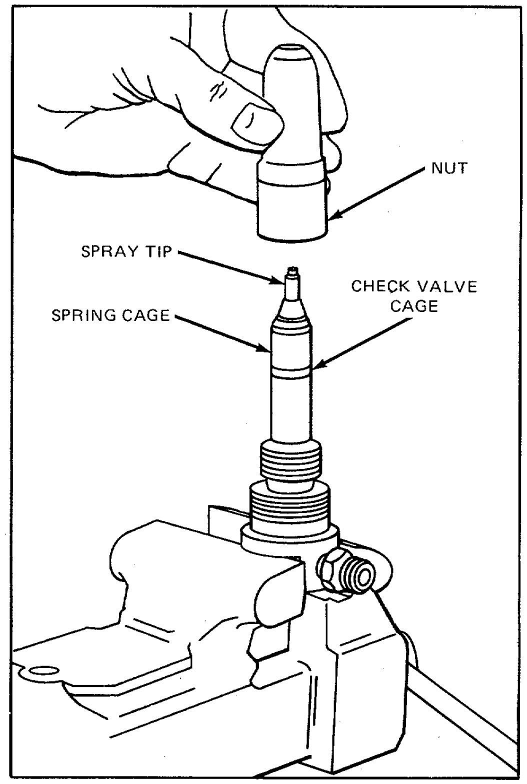


Figure 14. Assembling Injector Valve Parts on Tip Tester Adaptor J 23010-129

3. Tighten the injector nut.

4. Mount the adaptor and assembled injector parts in the support bracket (adaptor plate not needed). Refer to Fig. 15.

5. Install the offset clamping head on the clamping post (on J 23010 testers without serial numbers, use the upper detent position and on J 23010 testers numbered 1051 and higher, use the lower detent position).

6. Select the (larger) 9/16-18 threaded coupling nut J 23010-20 and thread it on tubing J 23010-75.

Install the tubing and fitting to adaptor J 23010-167.

7. Connect the tubing to tip-test adaptor J 23010-129 by threading the coupling nut on the tip-test adaptor.

Installing Adaptor and Tube Assembly on Tester J 23010

1. Position the adaptor and tubing assembly with the solid projecting end located in the hole on the left side of the support bracket.

2. Swing the clamping head over the adaptor and clamp it with the oil supply outlet aligned over the open projecting end of the adaptor (Fig. 15).

NOTE

Use the fuel injector clamping procedure to clamp adaptor J 23010-167 in the injector tester.

Spray Tip Test

1. Move lever 4 down and operate pump lever 1 rapidly with smooth, even strokes (40 strokes per minute), simulating the action of the tip functioning in the engine (Fig. 13).

2. Note the pressure at which the needle valve opens on gage 1. The valve should open between 2200 and 3200 psi (15 158 and 22 048 kPa). The opening and closing action should be sharp and produce a normal, finely atomized spray pattern.

If the valve opening pressure is below 2200 psi (15 158 kPa) and/or atomization is poor, the cause is usually a weak valve spring or a poor needle valve seat.

If the valve opening pressure is within 2200-3200 psi (15 158-22 048 kPa) or 1700-2300 psi (11 713-15 847 kPa) for the L-40 injector, proceed to check for spray tip leakage as follows:

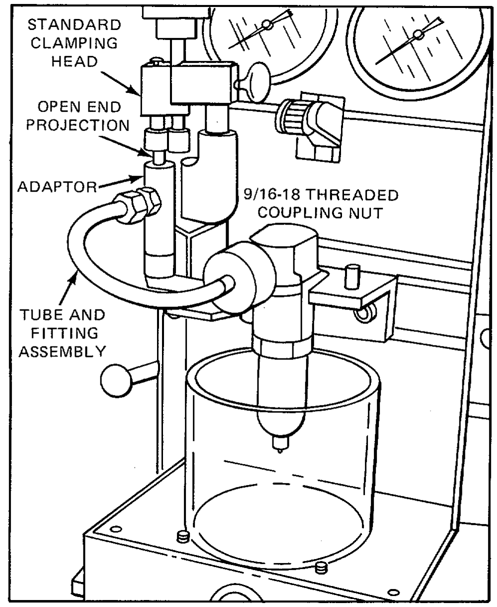


Figure 15. Adaptor and Tube Assembly on Injector Tester J23010

NOTE

When testing for spray tip leakage using the auxiliary tester, be sure to use the proper spring for the valve tip being tested.

a. Actuate pump lever 1 several times and hold the pressure at 1500 psi (10 335 kPa) for 15 seconds.

b. Inspect the spray tip for leakage. There should be no fuel droplets, although a slight wetting at the spray tip is permissible.

Needle Valve Lift Test

To measure the needle valve lift, use tool J 9462-01 (Fig. 16) as follows:

1. Zero the indicator by placing the bottom surface of the plunger assembly on a flat surface and zero the indicator dial.

2. Place the spray tip and needle valve assembly tight against the bottom of the gage with the quill of the needle valve in the hole in the plunger.

3. While holding the spray tip and needle valve assembly tight against the gage, read the needle valve lift on the indicator. The lift should be 0.008 to 0.018 inch. If it exceeds 0.018 inch, the tip assembly must be replaced. If it is less than 0.008 inch, inspect for foreign material between the needle valve and the tip seat.

4. If the needle valve lift is within limits, install a new needle valve spring and recheck the valve opening pressure and valve action. Low valve opening pressure or poor atomization with a new spring and seat indicates the spray tip and needle valve assembly should be replaced.

5. Reassemble the injector as outlined under Assemble Injector and check the injector output with calibrator J 22410.

Needle Valve Tip Test (Using Auxiliary Tester J 22640)

1. Connect the pipe from auxiliary tester J 22640 to the rear of the J 23010 tester at the connection located near the bottom of the tester (Fig. 17).

2. Assemble cleaned injector parts, including the check valve cage, spring, spring seat, spring cage, and spray tip assembly, on auxiliary tester J 22640 (Fig. 18).

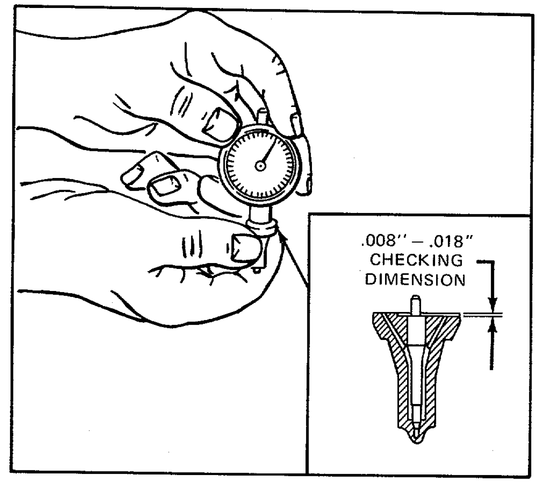


Figure 16. Checking Needle Valve Lift with Tool J 9462-02

3. Carefully pilot the injector nut over the spray tip and valve parts and thread it on the auxiliary tester.

4. Tighten the injector nut.

5. Open the valve on the auxiliary tester and place lever 4 in the up (horizontal) position.

6. Install the shield on the auxiliary tester and operate pump lever 1 until the needle valve has opened several times to purge the air from the system.

7. Operate pump lever 1 rapidly with smooth even strokes (40 strokes-per- minute) simulating the action of the tip functioning in the engine. Note the pressure at which the test oil delivery occurs. Test oil delivery should occur between 2200 and 3200 psi (15 158 and 22 048 kPa) except for the L-40 injector which should open between 1700 and 2300 psi (11 713 and 15 847 kPa). The beginning and ending of delivery should be sharp and the test oil should be a finely atomized spray.

If the valve opening pressure is below 2200 psi (15 158 kPa) or 1700 psi (11 713 kPa) for the L-40 injector and/or atomization is poor, the cause is usually a weak valve spring or poor needle valve seat.

If the valve opening pressure is within 2200-3200 psi (15 158-22 048 kPa) or 1700-2300 psi (11 713-15 847 KPa) for the L-40 injector, proceed to check for spray tip leakage as follows:

NOTE

When testing for spray tip leakage using the auxiliary tester, be sure to use the proper spring for the valve tip being tested.

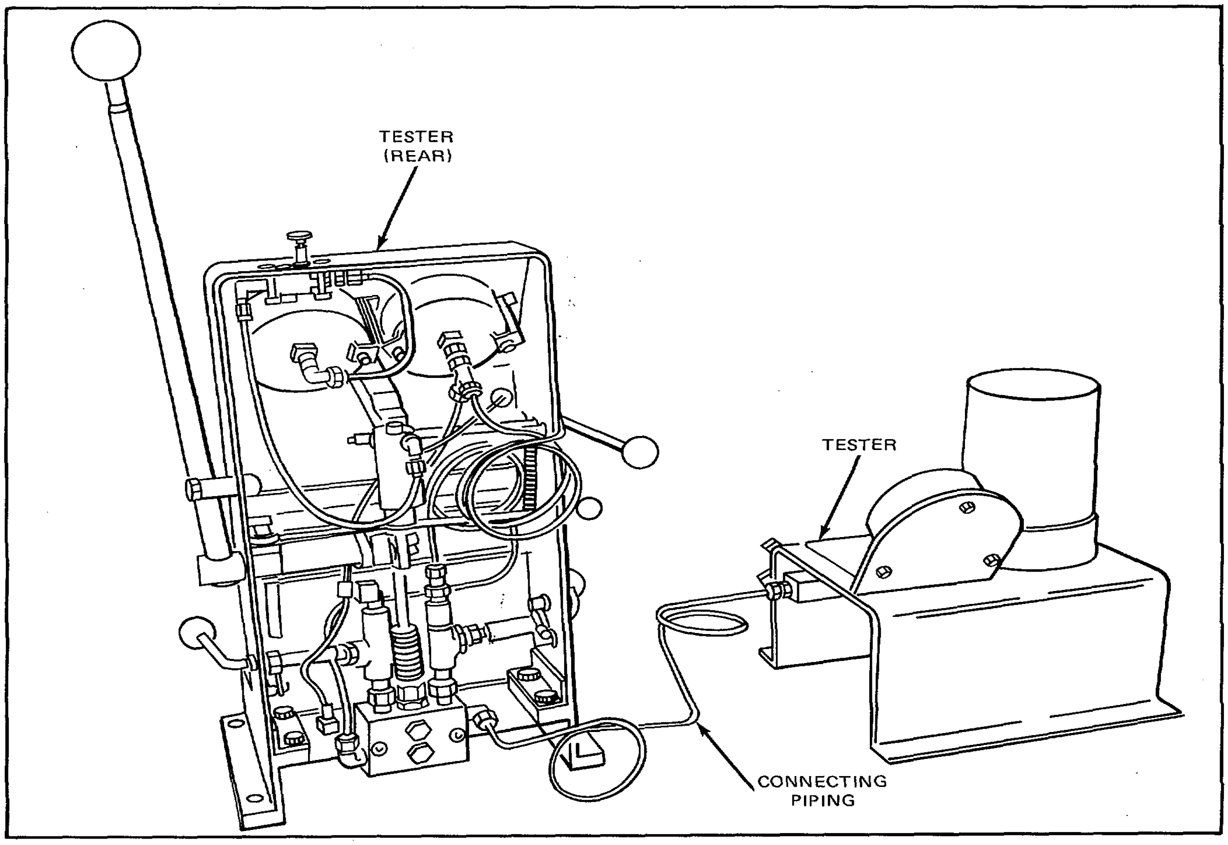


Figure 17. Injector Needle Valve Tester J 23010 with Auxiliary Tester J 22640

a. Actuate the pump lever several times and hold the pressure at 1500 psi (10 335 kPa) for 15 seconds.

b. Inspect the spray tip for leakage. There should be no fuel droplets although a slight wetting at the spray tip is permissible.

Perform the needle valve lift test.

Fuel Output Test

Perform the injector fuel output test in calibrator J 22410. When injectors are removed from an engine for fuel output testing and, if satisfactory, reinstalled without disassembly, extreme care should be taken to avoid reversing the fuel flow. When the fuel flow is reversed, dirt trapped by the filter is back-flushed into the injector components.

Before removing an injector from the engine, note the direction of the fuel flow. To avoid reversing the fuel flow when checking injector fuel output, use the appropriate adaptor. The position of the braided fuel inlet tube and the plastic fuel outlet tube on the calibrator (Fig. 20) depends on the adaptor being used and the direction of fuel flow through the injector.

Calibrator J 22410

To check the fuel output, operate the injector in calibrator J 22410 (Fig. 21) as follows:

NOTE

Place the cam shift index wheel and fuel flow lever in their respective positions. Turn on the test fuel oil heater switch and preheat the test oil to 95- 105°F (35-400C).

1. Place the proper injector adaptor between the tie rods and engage it with the fuel block locating pin. Then slide the adaptor forward and up against the fuel block face.

2. Place injector seat J 22410-226 into the permanent seat (cradle handle in vertical position). Clamp the in- jector into position by operating the air valve.

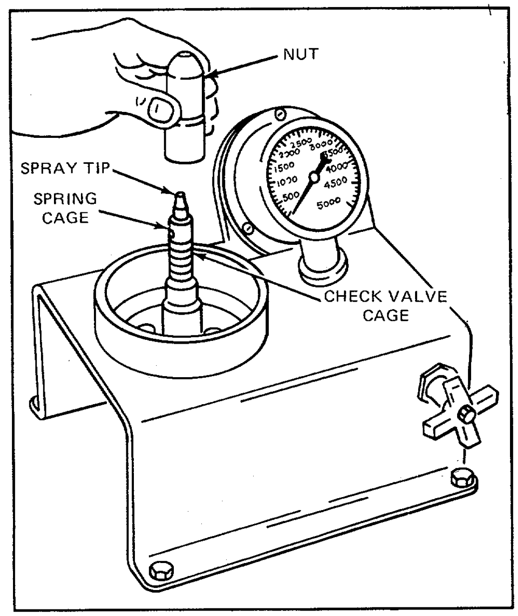


Figure 18. Installing Injector Valve parts on Auxiliary Tester J 22640

NOTE

Make sure the counter (Fig. 22) on the calibrator is preset at 1000 strokes. If for any reason this setting has been altered, reset the counter to 1000 strokes by twisting the cover release button to the left and hold the reset lever in the full up position while setting the numbered wheels. Close the cover. Refer to the calibrator instruction booklet for further information.

3. Pull the injector rack out to the no-fuel position.

4. Turn on the main power control circuit switch. Then start the calibrator by turning on the motor starter switch.

NOTE

The low oil pressure warning buzzer will sound briefly until the lubricating oil reaches the proper pressure.

5. After the calibrator has started, set the injector rack into the full-fuel position. Allow the injector to operate for approximately 30 seconds to purge the air that may be in the system.

6. After the air is purged, press the fuel flow start button (red). This will start the flow of fuel into the vial. The fuel flow to the vial will automatically stop after 1000 strokes.

7. Shut the calibrator off (the calibrator will stop in less time at full-fuel).

8. Observe the vial reading and refer to Fig. 19 to determine whether the injector fuel output falls within the specified limits. If the quantity of fuel in the vial does not fall within the specified limits, refer to Troubleshooting Chart 6 and Shop Notes in Specifications and Troubleshooting for the cause and remedy.

NOTE

Refer to Specifications and Troubleshooting for different factors that may affect the injector calibrator output reading.

The calibrator may be used to check and select a set of injectors which will inject the same amount of fuel in each cylinder at a given throttle setting, resulting in a smooth-running, well-balanced engine.

Injector	Calibrator J 22410	
	Min.	Max.
N35	36	41
L40	41	46
N40	42	47
N45	47	52
N50	50	55
C40	42	47
C45	47	52
C50	50	55
5A50	53	58
5A55	56	61
5A60	63	68
N55	53	58
N60	57	62
N65	64	69
5N65	64	69
N70	71	76
M60	60	65
M70	73	77

Figure 19. Fuel Output Chart.

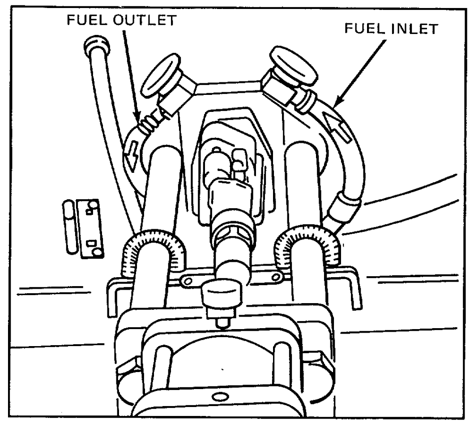


Figure 20. Position of Calibrator Fuel Flow Pipes.

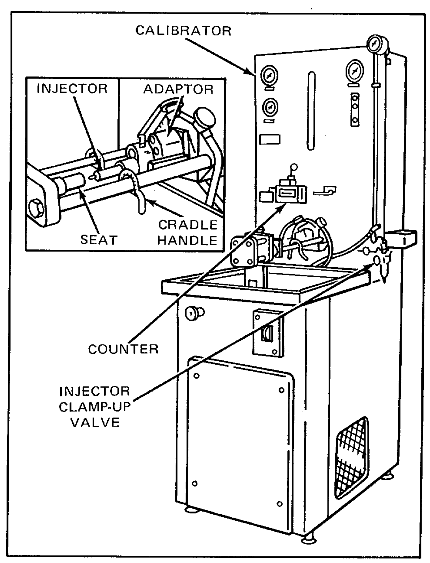


Figure 21. Injector in Calibrator J 22410

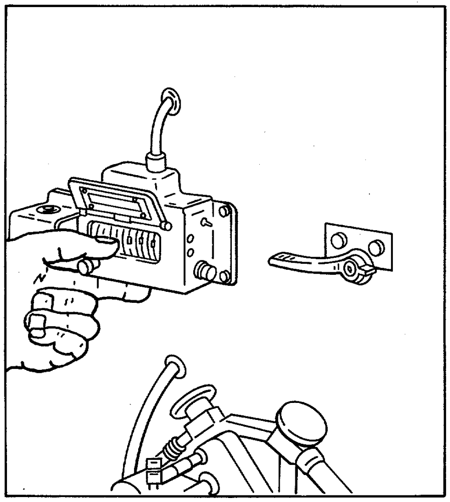


Figure 22. Setting Calibrator Stroke Counter.

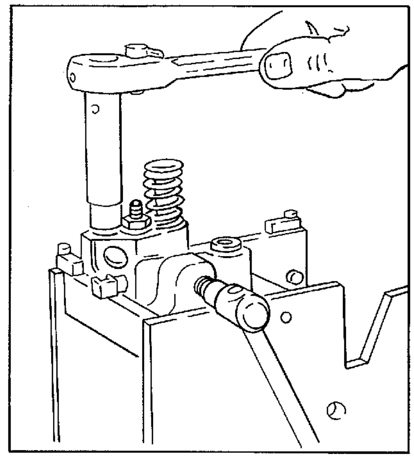


Figure 23. Removing or Installing Filter Cap

An injector which passes all of the above tests may be put back into service. However, an injector which fails to pass one or more of the tests must be rebuilt and checked on the calibrator.

Any injector which is disassembled and rebuilt must be tested again before being placed in service.

Disassemble Injector

If required, disassemble an injector as follows:

1. Support the injector upright in injector holding fixture J 22396 (Fig. 23) and remove the filter caps, gaskets, and filters.

CAUTION

> Whenever a fuel injector is disassembled, discard the filters and gaskets and replace with new filters and gaskets.

In the offset injector, a filter is used in the inlet side only. No filter is required in the outlet side (Fig. 35).

2. Compress the follower spring as shown in Fig. 11. Then raise the spring above the stop pin with a screw-driver and withdraw the pin. Allow the spring to rise gradually.

3. Refer to Fig. 24 and remove the plunger follower, plunger, and spring as an assembly.

4. Invert the fixture and, using socket J 4983-01, loosen the nut on the injector body (Fig. 25).

5. Lift the injector nut straight up, being careful not to dislodge the spray tip and valve parts. Remove the spray tip and valve parts from the bushing and place them in a clean receptacle until ready for assembly.

When an injector has been in use for some time, the spray tip, even though clean on the outside, may not be pushed readily from the nut with the fingers.

In this event, support the nut on a woodblock and drive the tip down through the nut, using tool J 1291-02 as shown in Fig. 26.

6. Refer to Fig. 37 and remove the spill deflector. Then lift the bushing straight out of the injector body.

7. Remove the injector body from the holding fixture. Turn the body upside down and catch the gear retainer and gear in your hand as they fall out of the body.

8. Withdraw the injector control rack from the injector body. Also remove the seal ring from the body.

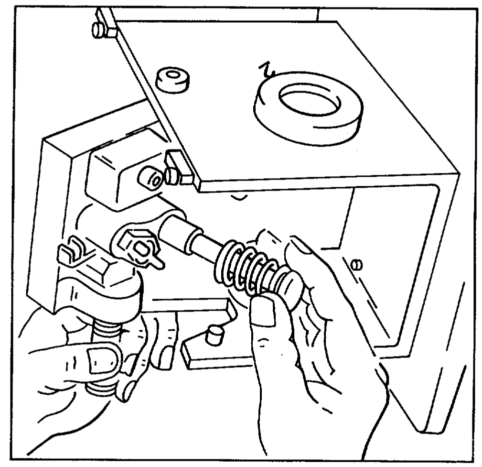


Figure 24. Removing or Installing Plunger Follower, Plunger and Spring.

Clean Injector Parts

Since most injector difficulties are the result of dirt particles, it is essential that a clean area be provided on which to place the injector parts after cleaning and inspection.

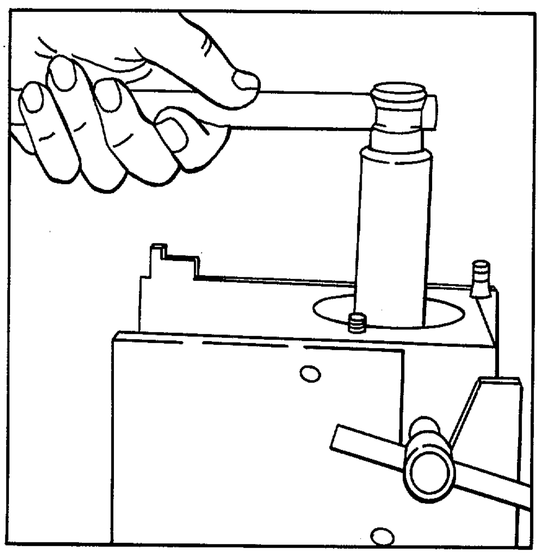


Figure 25. Removing Injector Nut using Tool J 4983-01

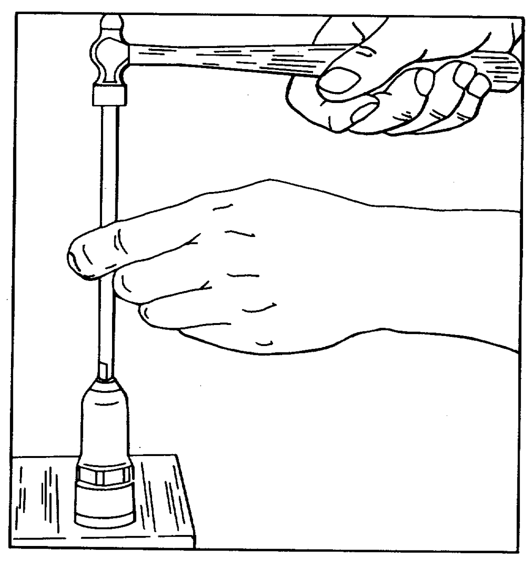


Figure 26. Removing Spray Tip from Injector Nut using Tool J 1291-02

Wash all of the parts with clean fuel oil or a suitable cleaning solvent and dry them with clean, filtered compressed air. DO NOT use waste or rags for cleaning purposes. Clean out all of the passages, drilled holes, and slots in all of the injector parts.

Carbon on the inside of the spray tip may be loosened for easy removal by soaking for approximately 15 minutes in a suitable solution prior to the external cleaning and buffing operation. Methyl Ethyl Ketone J 8257 solution is recommended for this purpose.

Clean the spray tip with tool J 9464-01 (Fig. 27).

CAUTION

Care must be exercised when inserting the carbon remover J 9464-01 in the spray tip to avoid contacting the needle valve seat in the tip.

Wash the tip in fuel oil and dry it with compressed air. Clean the spray tip orifices with pin vise J 4298-1 and the proper size spray tip cleaning wire. Use wire J 21460 to clean 0.0055-inch-diameter holes and wire J 21461 to clean 0.006-inch-diameter holes (Fig. 28).

Before using the wire, hone the end until it is smooth and free of burrs and taper the end a distance of 1/16 inch with stone J 8170. Allow the wire to extend 1/8 inch from tool J 4298-1.

The exterior surface of an injector spray tip may be cleaned by using a brass wire buffing wheel, tool J 7944. To obtain a good polishing effect and longer brush life, the buffing wheel should be installed on a motor that turns the wheel at approximately 3000 rpm. A convenient method of holding the spray tip while cleaning and polishing is to place the tip over the drill end of spray tip cleaner tool J 1243 and hold the body of the tip against the buffing wheel. In this way, the spray tip is rotated while being buffed.

NOTE

DO NOT buff excessively. DO NOT use a steel wire buffing wheel or the spray tip holes may be distorted.

When the body of the spray tip is clean, lightly buff the tip end in the same manner. This cleans the spray tip orifice area and will not plug the orifices

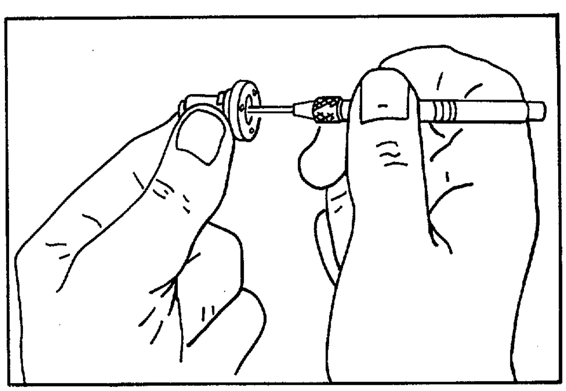


Figure 27. Cleaning Injector Spray Tip with Tool J 24838

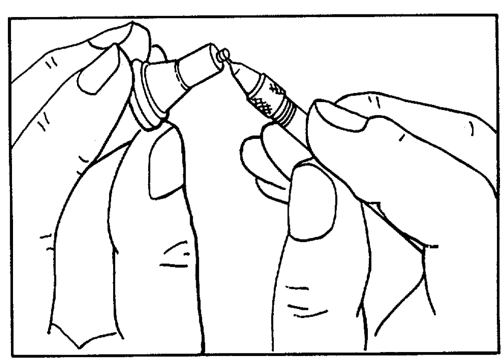


Figure 28. Cleaning Spray Tip Orifices with Tool J 4298-1

Wash the spray tip in clean fuel oil and dry it with compressed air.

Clean and brush all of the passages in the injector body using fuel hole cleaning brush J 8152 and rack hole cleaning brush J 8150. Blow out the passages and dry them with compressed air.

Carefully insert reamer J 21089 in the injector body (Fig. 29). Turn it in a clockwise direction a few turns, then remove the reamer and check the face of the ring for reamer contact over the entire face of the ring. If necessary, repeat the reaming procedure until the reamer does make contact with the entire face of the ring. Clean up the opposite side of the ring in the same manner.

Carefully insert a 0.375-inch-diameter straight-fluted reamer inside the ring bore in the injector body. Turn the reamer in a clockwise direction and remove any burrs inside the ring bore. Then wash the injector body in clean fuel oil and dry it with compressed air.

Remove the carbon deposits from the lower inside diameter taper of the in- jector nut with carbon remover J 9418-5 (Fig. 30). Use care to minimize removing metal or setting up burrs on the spray tip seat. Remove only enough metal to produce a clean uniform seat to prevent leakage between the tip and the nut. Carefully insert carbon re- mover J 9418-1 in the injector nut. Turn it clockwise to remove the carbon deposits on the flat spray tip seat.

Wash the injector nut in clean fuel oil and dry it with compressed air. Carbon deposits on the spray tip seating surface of the injector nut will result in poor sealing and consequent fuel leakage around the spray tip.

When handling the injector plunger, do not touch the finished plunger surfaces with your fingers. Wash the plunger and bushing with clean fuel oil and dry them with compressed air. Be sure the high-pressure bleed hole in the side of the bushing is not plugged. If this hole is plugged, fuel leakage will occur at the upper end of the bushing where it will drain out of the injector body vent and rack holes during engine operation, causing a serious oil dilution problem.

NOTE

Keep the plunger and bushing together, as they are mated parts.

After washing, submerge the parts in a clean receptacle containing clean fuel oil.

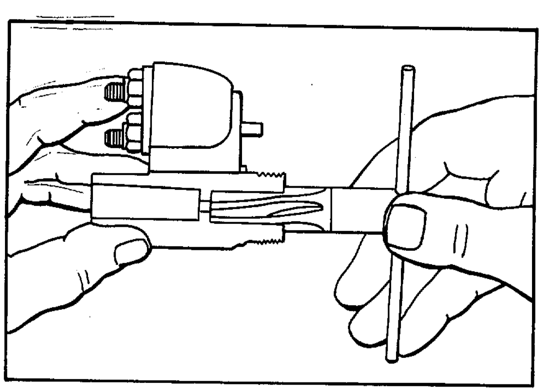


Figure 29. Cleaning Injector Body Ring with Tool J 21089

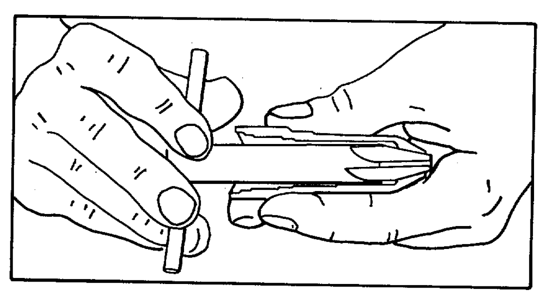


Figure 30. Cleaning Injector Nut Spray Tip with Tool J 9418-5

NOTE

Keep the parts of each injector assembly together.

Inspect Injector Parts

Inspect the teeth on the control rack and the control rack gear for excessive wear or damage. Also check for excessive wear in the bore of the gear and inspect the gear retainer. Replace damaged or worn parts.

Inspect the injector follower and pin for wear. Refer to *Specifications and Troubleshooting*.

Inspect both ends of the spill deflector for sharp edges or burrs which could create burrs on the injector body or injector nut and cause particles of metal to be introduced into the spray tip and valve parts. Remove burrs with a 500-grit stone.

Inspect the follower spring for visual defects. Then check the spring with spring tester J 22738-02.

The current injector follower spring (0.142-inch-diameter wire) has a free length of approximately 1.504 inches and should be replaced when a load of less than 70 lbs. will compress it to 1.028 inches.

It is recommended that at the time of overhaul, all injectors in an engine be converted to the current spring (0.142-inch-diameter wire) which will provide improved cam roller-to-shaft follow. However, in the event that one or two injectors are changed, the remaining injectors need not be reworked to incorporate the current spring.

Check the seal ring area on the injector body for burrs or scratches. Also check the surface which contacts the injector bushing for scratches, scuff marks or other damage. If necessary, lap this surface. A faulty sealing surface at this point will result in high fuel consumption and contamination of the lubricating oil. Replace any loose injector body plugs or a loose dowel pin. Install the proper number tag on a service replacement injector body.

Inspect the injector plunger and bush- ing for scoring, erosion, chipping, or wear. Check for sharp edges on that portion of the plunger which rides in the gear. Remove any sharp edges with a 500-grit stone. Wash the plunger after stoning it. Injector bushing inspectalite J 21471 can be used to check the port holes in the inner diameter of the bushing for cracks or chipping. Slip the plunger into the bushing and check for free movement.

NOTE

Replace the plunger and bush- ing as an assembly if any of the above damage is noted, since they are mated parts.

Use new mated factory parts to assure the best performance from the injector.

Injector plungers cannot be reworked to change the output. Grinding will destroy the hardened case at the helix and result in chipping and seizure or scoring of the plunger.

Examine the spray tip seating surface of the injector nut and spray tip for nicks, burrs, erosion, or brinelling. Reseat the surface or replace the nut or tip if it is severely damaged.

The injector valve spring plays an important part in establishing the valve opening pressure of the injector assembly. Replace a worn or broken spring.

Inspect the sealing surfaces of the in- jector parts indicated by arrows in Fig. 31. Examine the sealing surfaces with a magnifying glass as shown in

Fig. 32, for even the slightest imperfections will prevent the injector from operating properly. Check for burrs, nicks, erosion, cracks, chipping, and excessive wear. Also check for enlarged orifices in the spray tip. Replace damaged or excessively worn parts. Check the minimum thickness of the lapped parts as noted in the chart.

Examine the seating area of the needle valve for wear or damage. Also examine the needle quill and its contact point with the valve spring seat. Replace damaged or excessively worn parts.

Examine the needle valve seat area in the spray tip for foreign material. The smallest particle of such material can prevent the needle valve from seat- ing properly. Polish the seat area with polishing stick J 22964. Coat only the tapered end of the stick with polishing compound J 23038 and insert it directly into the center of the spray tip until it bottoms. Rotate the stick 6 to 12 times, applying a light pressure with the thumb and forefinger.

CAUTION

Be sure that no compound is accidentally placed on the lapped surfaces located higher up in the spray tip. The slightest lapping action on these surfaces can alter the near-perfect fit between the needle valve and tip.

Before reinstalling used injector parts, lap all of the sealing surfaces indicated by the arrows in Fig. 31. It is also good practice to lightly lap the sealing surfaces of new injector parts which may become burred or nicked during handling.

NOTE

The sealing surface of current spray tips is precision lapped by a new process which leaves the surface with a dull satin-like finish; the lapped surface on former spray tips was bright and shiny (Fig. 34). It is not recommended or necessary to lap the surface of a new current spray tip.

Lapping Injector Parts

Lap the sealing surfaces indicated in Fig. 31 and Table 1 as follows:

1. Clean lapping blocks J 22090 with compressed air. Do not use a cloth or any other material for this purpose.

2. Spread a good quality 600-grit dry lapping powder on one of the lapping blocks.

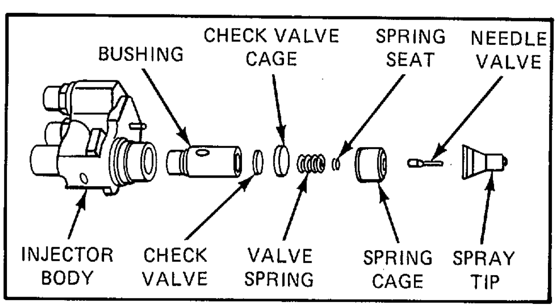


Figure 31. Sealing Surfaces which may Require Lapping

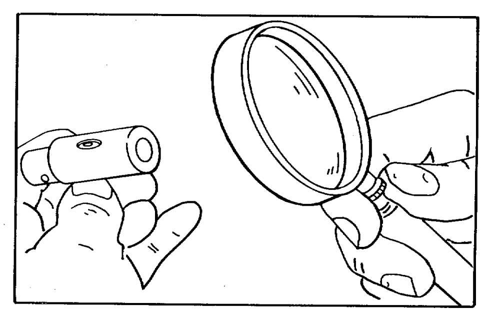


Figure 32. Examining Sealing Surfaces with a Magnifying Glass

3. Place the part to be lapped flat on the block as shown in Fig. 33 and, using a figure eight motion, move it back and forth across the block. Do not press on the part, but use just enough pressure to keep the part flat on the block. It is important that the part be kept flat on the block at all times.

4. After each four or five passes, clean the lapping powder from the part by drawing it across a clean piece of tissue placed on a flat surface and inspect the part. DO NOT lap excessively (refer to Table 1).

5. When the part is flat, wash it in cleaning solvent and dry it with compressed air.

6. Place the dry part on the second block. After applying lapping powder, move the part lightly across the block in a figure eight motion several times to give it a smooth finish. DO NOT lap excessively. Again, wash the part in cleaning solvent and dry it with com- pressed air.

7. Place the dry part on the third block. Do not use lapping powder on this block. Keep the part flat and move it across the block several times, using the figure eight motion. Lapping the dry part in this manner gives it the mirror finish required for perfect sealing.

TABLE 1. Minimum Thickness
(Used Parts)

Part Name	Minimum Thickness
Spray Tip (Shoulder	0.199 inch
Check Valve Cage	0.163 - 0.165 inch
Check Valve	0.022 inch
Valve Spring Cage	0.602 inch

8. Wash all of the lapped parts in clean fuel oil and dry them with compressed air.

ASSEMBLE INJECTOR

Use an extremely clean bench to work on and to place the parts when assembling an injector. Also be sure all of the injector parts, both new and used, are clean.

Study Fig. 35 through 38 for the proper relative position of the injector parts, then proceed as follows:

Assemble Injector Filters

Always use new filters and gaskets when reassembling an injector.

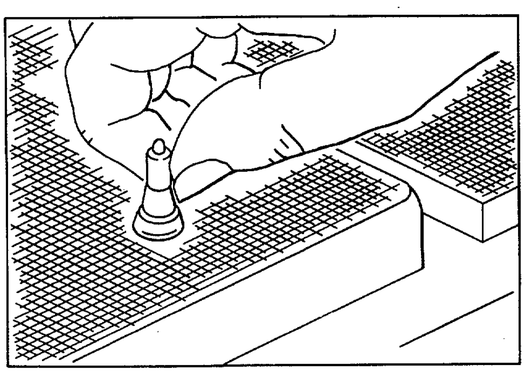


Figure 33. Lapping Spray Tip on Lapping Blocks J 22090

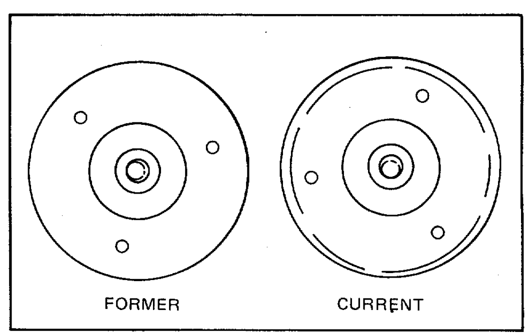


Figure 34. Spray Tip Sealing Surface Identification

1. Insert a new filter, dimple end down, slotted end up, in each of the fuel cavities in the top of the injector body (Fig. 36).

NOTE

Install a new filter in the inlet side (located over the injector rack) in a fuel injector with an offset body. No filter is required in the outlet side of the offset body injector (Fig. 35).

2. Place a new gasket on each filter cap. Lubricate the threads and install the filter caps. Tighten the filter caps to 65-75 lb ft (88-102 Nm) torque with a 9/16-inch deep socket (Fig. 23).

3. Purge the filters after installation by directing compressed air or fuel through the filter caps.

4. Install clean shipping caps on the filter caps to prevent dirt from entering the injector.

Assemble Rack and Gears

Refer to Fig. 37 and note the drill spot marks on the control rack and gear. Then proceed as follows:

1. Hold the injector body, bottom end up, and slide the rack through the hole in the body. Look into the body bore and move the rack until you can see the drill marks. Hold the rack in this position.

2. Place the gear in the injector body so that the marked tooth is engaged between the two marked teeth on the rack (Fig. 37).

3. Place the gear retainer on top of the gear.

4. Align the locating pin in the bushing with the slot in the injector body, then slide the end of the bushing into place.

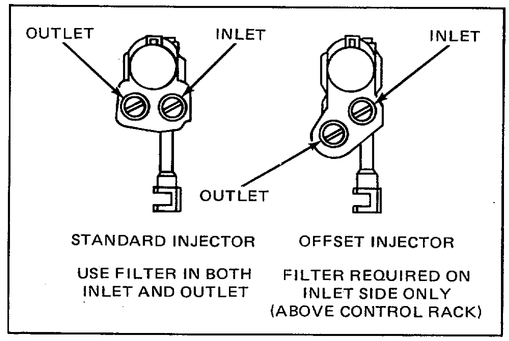


Figure 35. Locator of Filter in Injector Body

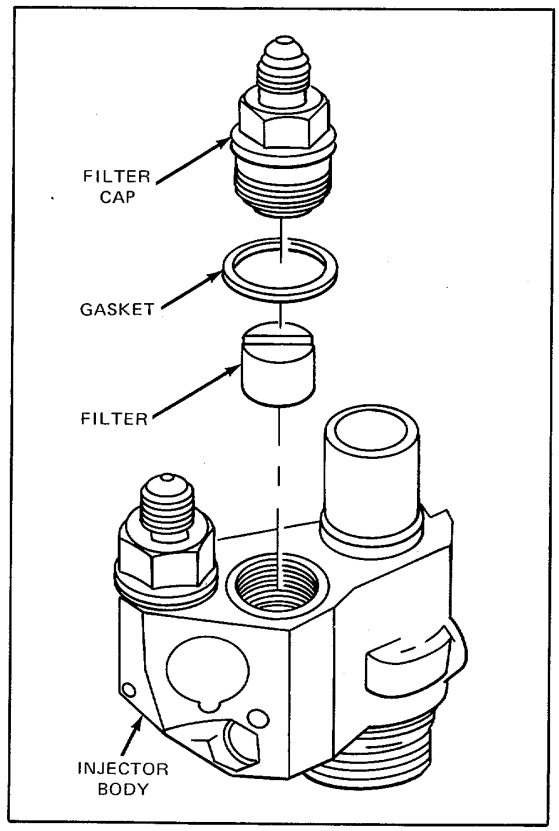


Figure 36. Details of Injector Filters and Caps and Their Relative Location

Assemble Spray Tip, Spring Cage and Check Valve Assemblies

Refer to Fig. 37 and assemble the parts as follows:

1. Support the injector body, bottom end up, in injector holding fixture J 22396.

2. Place a new seal ring on the shoulder of the body.

CAUTION

Wet the seal ring with test oil and install the ring all the way down past the threads and onto the shoulder of the injector body. This will prevent the seal from catching in the threads and becoming shredded.

A new injector nut seal ring protector (J 29197) is now available to install the seal ring. Use the following procedure when installing the seal ring with the new protector:

a. Place a new seal ring and protector in a container with a small amount of injector test oil.

CAUTION

Lubrication of the seal ring and protector is important to assure proper installation of the seal ring.

b. Support the injector body, bottom end up, in injector holding fixture J 22396.

c. Place the lubricated protector over the threads of the injector body. Place the new seal over the nose of the protector and down onto the shoulder of the injector body. Do not allow the seal to roll or twist.

d. Remove the protector.

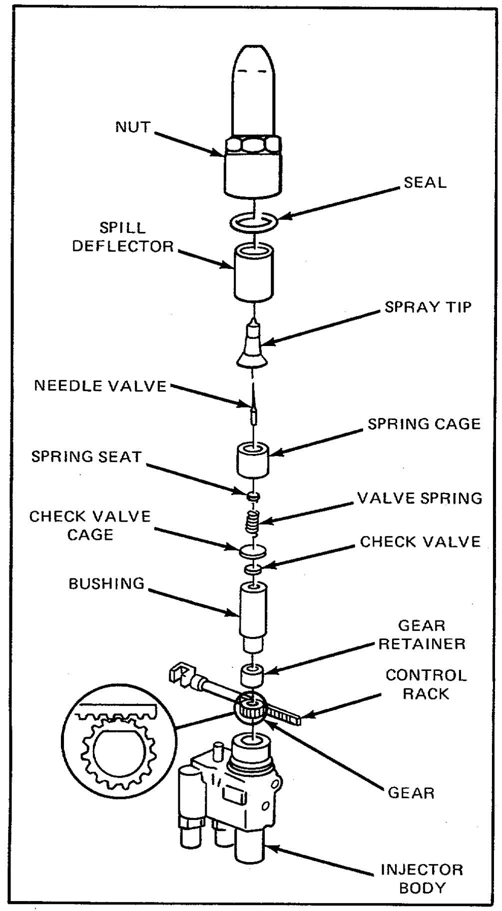


Figure 37. Injector Rack, Gear, Spray Tip, and Valve Assembly Details and Relative Location of Parts

3. Install the spill deflector over the barrel of the bushing.

4. Place the check valve (without the 0.010-inch hole) centrally on the top of the bushing. Then place the check valve cage over the check valve and against the bushing.

CAUTION

The former and new check valve and check valve cage are not separately interchangeable in a former injector (Fig. 39).

5. Insert the spring seat in the valve spring, then insert the assembly into the spring cage, spring seat first.

CAUTION

Install a new spring seat (Fig. 39) in a former injector if a new design spray tip assembly is used.

6. Place the spring cage, spring seat, and valve spring assembly (valve spring down) on top of the check valve cage.

CAUTION

When installing a new spray tip assembly in a former injector, a new valve spring seat must also be installed. The current needle valve has a shorter quill.

7. Insert the needle valve, tapered end down, inside of the spray tip (Fig. 2). Then place the spray tip and needle valve on top of the spring cage with the quill end of the needle valve in the hole in the spring cage.

8. Lubricate the threads in the injector nut and carefully thread the nut on the injector body by hand. Rotate the spray tip between your thumb and first finger while threading the nut on the injector body (Fig. 40). Tighten the nut as tight as possible by hand. At this point, there should be sufficient force on the spray tip to make it impossible to turn with your fingers.

9. Use socket J 4983-01 and a torque wrench to tighten the injector nut to 75-85 lb ft (102-115 Nm) torque (Fig. 41).

10. After assembling a fuel injector, always check the area between the nut and the body. If the seal is still visible after the nut is assembled, try another nut which may allow assembly on the body without extruding the seal and forcing it out of the body-nut crevice.

CAUTION

Do not exceed the specified torque. Otherwise, the nut may be stretched and result in improper sealing of the lapped surfaces in a subsequent injector overhaul.

Assemble Plunger and Follower

1. Refer to Fig. 38 and slide the head of the plunger into the follower.

2. Invert the injector in the assembly fixture, filter cap end up, and push the rack all the way in. Then place the follower spring on the injector body.

3. Refer to Fig. 42 and place the stop pin on the injector body so that the follower spring rests on the narrow flange of the stop pin. Then align the slot in the follower with the stop pin hole in the injector body. Next align the flat side of the plunger with the slot in the follower. Then insert the free end of the plunger in the injector body. Press down on the follower and at the same time press the stop pin into position. When in place, the spring will hold the stop pin in position.

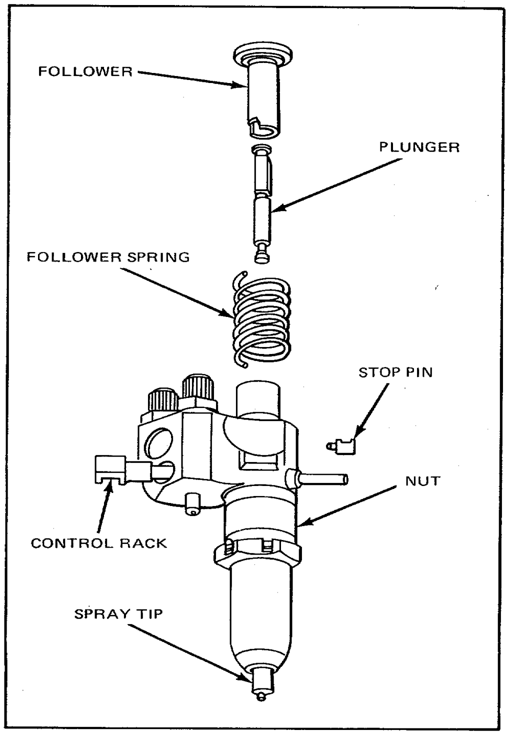


Figure 38. Injector Plunger, Follower and Relative Location of Parts

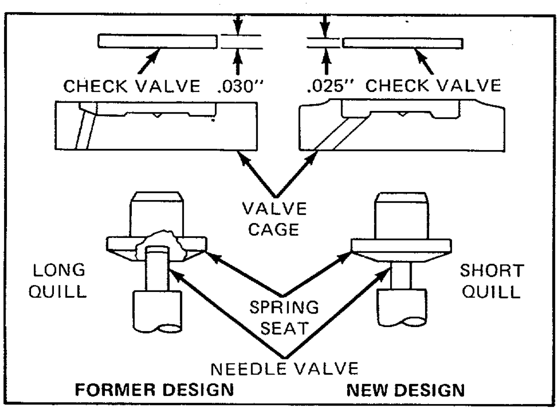


Figure 39. Comparison of Former and New Design Injector Parts

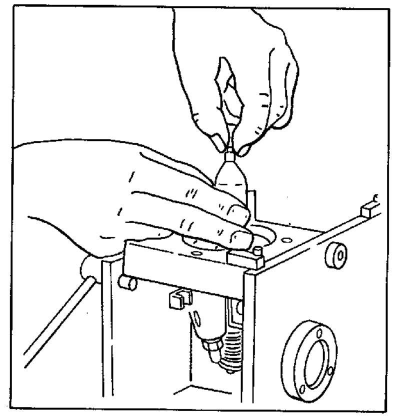


Figure 40. Tightening Injector Nut by Hand

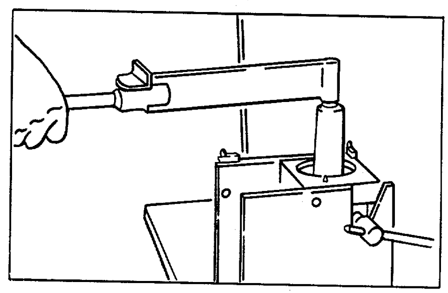


Figure 41. Tightening Injector Nut With Torque Wrench and Tool J 4983-01

Check Spray Tip Concentricity

To assure correct alignment, check the concentricity of the spray tip as follows:

1. Place the injector in the concentricity gage J 5119 as shown in Fig. 43 and adjust the dial indicator to zero.

2. Rotate the injector 360° and note the total runout as indicated on the dial.

3. If the total runout exceeds 0.008 inch, remove the injector from the gage. Loosen the injector nut, center the spray tip, and tighten the nut to 75-85 lb ft (102-115 Nm) torque. Recheck the spray tip concentricity. If, after several attempts, the spray tip cannot be positioned satisfactorily, replace the injector nut.

Test Reconditioned Injector

Before placing a reconditioned injector in service, perform all of the tests (except the visual inspection of the plunger) previously outlined under *Test Injector.*

The injector is satisfactory if it passes these tests. Failure to pass any one of the tests indicates that defective or dirty parts have been assembled. In this case, disassemble, clean, inspect, reassemble, and test the injector again.

Install Injector

Before installing an injector in an engine, remove the carbon deposits from the beveled seat of the injector tube in the cylinder head. This will assure correct alignment of the injector and prevent any undue stresses from being exerted against the spray tip.

Use injector tube bevel reamer J 5286-9, *Injector Tube*, to clean the carbon from the injector tube. Exercise care to remove ONLY the carbon so that the proper clearance between the injector body and the cylinder head is maintained. Pack the flutes of the reamer with grease to retain the carbon removed from the tube.

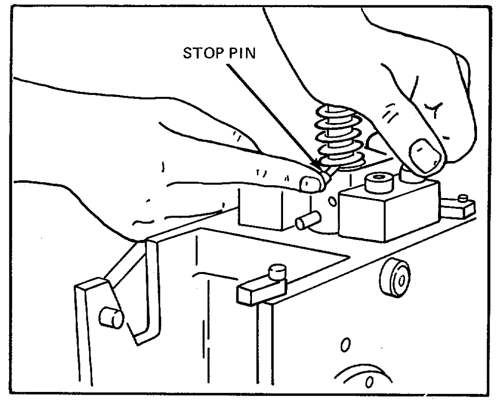


Figure 42. Installing Injector Following Stop Pin

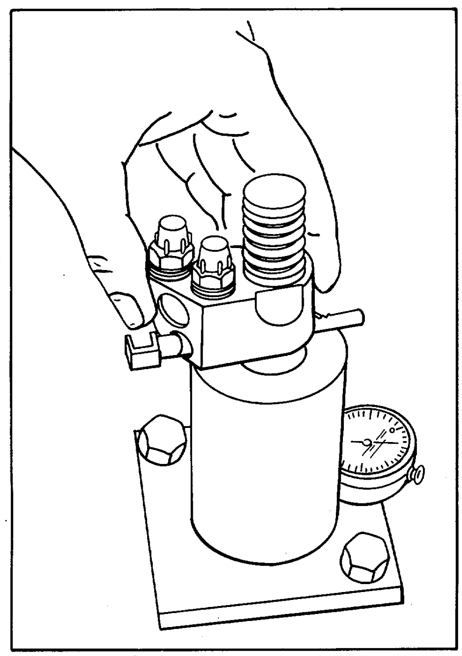


Figure 43. Checking Injector Spray Tip Concentricity with Tool J 5119.

Be sure the fuel injector is filled with fuel oil. If necessary, add clean fuel oil at the inlet filter cap until it runs out of the outlet filter cap.

Install the injector in the engine as follows:

1. Refer to Fig. 6 and insert the injector into the injector tube with the dowel pin in the injector body registering with the locating hole in the cylinder head.

2. Slide the injector rack control lever over so that it registers with the injector rack.

3. Install the injector clamp, special washer (with curved side toward injector clamp) and bolt. Tighten the bolt to 20-25 lb ft (27-34 Nm) torque. Make sure that the clamp does not interfere with the injector follower spring or the exhaust valve springs.

CAUTION

Check the injector control rack for free movement. Excess torque can cause the control rack to stick or bind.

4. Move the rocker arm assembly into position and secure the rocker arm brackets to the cylinder head by tightening the bolts to the torque specified in *Specification*.

CAUTION

On four valve cylinder heads, there is a possibility of damaging the exhaust valves if the exhaust valve bridge is not resting on the ends of the exhaust valves when tightening the rocker shaft bracket bolts. Therefore, note the position of the exhaust valve bridge (Fig. 44) before, during, and after tightening the rocker shaft bolts.

5. Remove the shipping caps. Then install the fuel pipes and connect them to the injector and the fuel connectors. Use socket J 8932-01 to tighten the connections to 12-15 lb ft (16-20 Nm) torque.

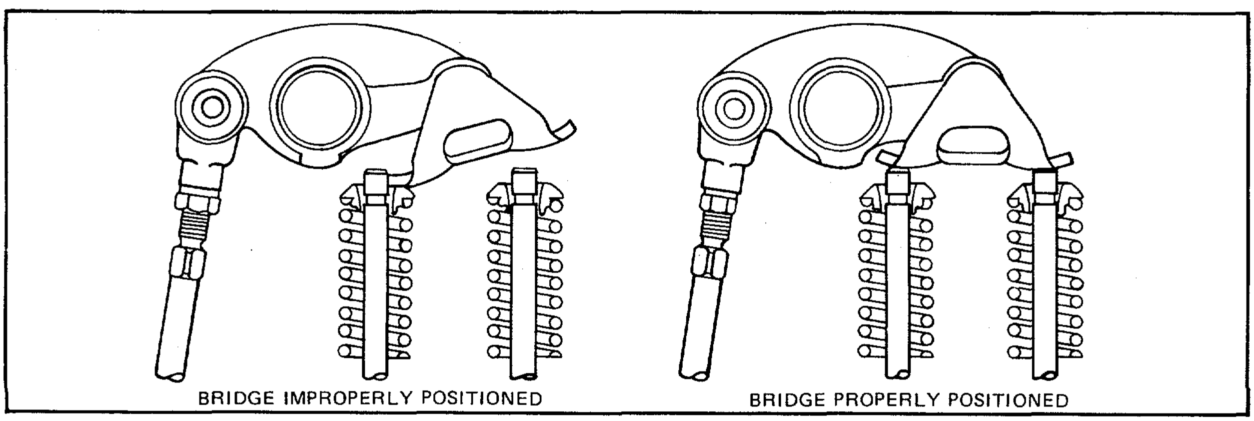


Figure 44. Relationship Between Exhaust Valve Bridge and Valve Stems.

CAUTION

Do not bend the fuel pipes and do not exceed the specified torque. Excessive tightening will twist or fracture the flared end of the fuel line and result in leaks. Lubricating oil diluted by fuel oil can cause serious damage to the engine bearings (refer to *Pressurize Fuel System - Check for Leaks*).

NOTE

An indication of fuel leakage at the fittings of the fuel injector supply lines and connector nut seals could be either low lubricating oil pressure (dilution) or fuel odor coming from the crankcase breathers or an open oil filler cap. When any of the above are detected, remove the valve rocker cover. A close inspection of the rocker cover, cylinder head, fuel lines, and connectors will usually show if there is a fuel leakage problem. Under normal conditions, there should be a coating of lubricating oil throughout the cylinder head area and puddles of oil where the fuel pipes contact the connectors and where the fuel connectors contact the cylinder head. If these areas do not have the normal coating of lubricating oil, it is likely that fuel oil is leaking and washing off the lubricating oil. Remove and replace the leaking fuel pipes and/or connectors. Reinstall the rocker cover. Then drain the lubricating oil and change the oil filter elements. Refer to *Fuel and Oil Specifications* and refill the crankcase to the proper level with the recommended grade of oil.

6. Perform a complete engine tuneup as outlined in *Engine Tuneup*. However, if only one injector has been removed and replaced and the other injectors and the governor adjustment have not been disturbed, it will only be necessary to adjust the valve clearance and time the injector for the one cylinder, and to position the injector rack control lever.

FUEL INJECTOR TUBE

The bore in the cylinder head for the fuel injector is directly through the cylinder head water jacket as shown in Fig. 1. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a tube is pressed into the injector bore. This tube is sealed at the top with a neoprene ring and upset into a flare on the lower side of the cylinder head to create water-tight and gas-tight joints at the top and bottom.

Remove Injector Tube

When removal of an injector tube is required, use injector tube service tool set J 22525 as follows:

1. Remove, disassemble, and clean the cylinder head as outlined in *Cylinder Head*.

2. Place injector tube installer J 5286-4 in the injector tube. Insert pilot J 5286-5 through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installer (Fig. 1).

3. Tap on the end of the pilot to loosen the injector tube. Then lift the injector tube, installer, and pilot from the cylinder head.

Install Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove dirt, burrs, or foreign material that may prevent the tube from seating at the lower end or sealing at the upper end. Then install the tube as follows:

1. Place a new injector tube seal ring in the counterbore in the cylinder head.

2. Place installer J 5286-4 in the injector tube. Then insert pilot J 5286-5 through the small opening of the injector tube and thread it into the tapped end of the installer (Fig. 2).

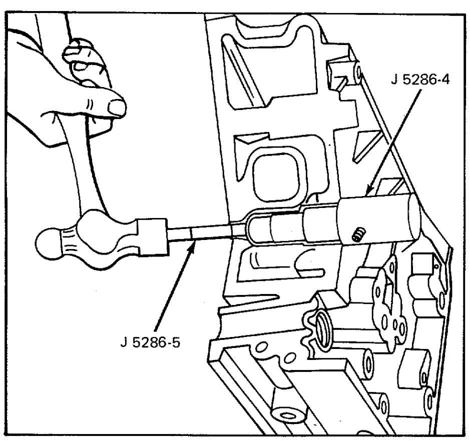


Figure 1. Removing Injector Tube.

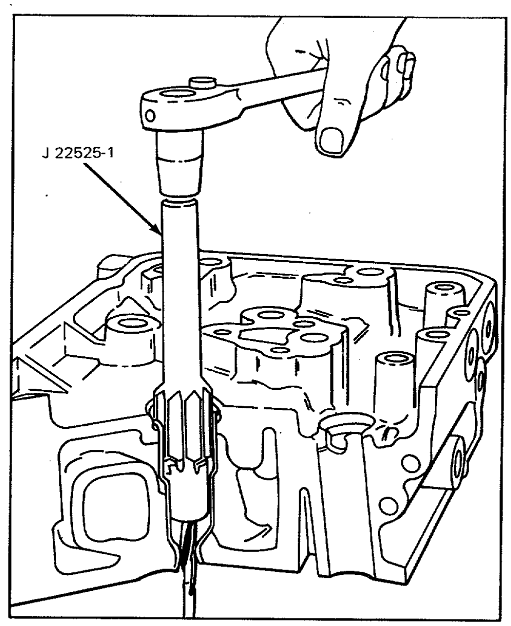


Figure 2. Installing Injector Tube.

3. Slip the injector tube into the injector bore and drive it in place as shown in Fig. 2. Sealing is accomplished between the head counterbore (inside diameter) and outside diameter of the injector tube. The tube flange is merely used to retain the seal ring.

4. With the injector tube properly positioned in the cylinder head, upset (flare) the lower end of the injector tube as follows:

a. Turn the cylinder head bottom side up, remove pilot J 5286-5 and thread upsetting die J 5286-6 into the tapped end of installer J 5286-4 (Fig. 3).

b. Then, using a socket and torque wrench, apply approximately 30 lb ft (41 Nm) torque on the upsetting die.

c. Remove the installing tools and ream the injector tube as outlined below.

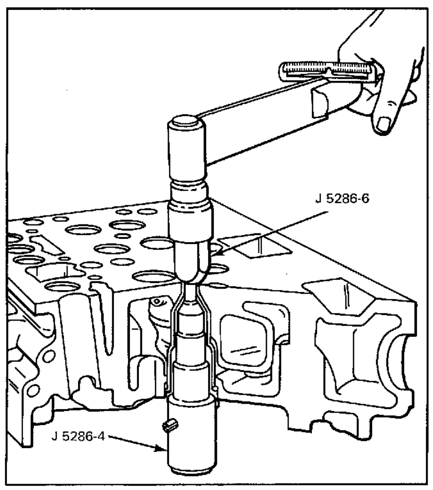


Figure 3. Upsetting Injector Tube.

Ream Injector Tube

After an injector tube has been installed in a cylinder head, it must be finished in three operations: First, hand reamed, as shown in Fig. 4, to receive the injector body nut and spray tip; second, spot-faced to remove excess stock at the lower end of the injector tube; and third, hand reamed, as shown in Fig. 5, to provide a good seating surface for the bevel or the lower end of the injector nut. Reaming must be done carefully and without undue force or speed so as to avoid cutting through the thin wall of the injector tube.

CAUTION

The reamer should be turned in a clockwise direction only, both when inserting and when withdrawing the reamer. Movement in the opposite direction will dull the cutting edges of the flutes.

1. Ream the injector tube for the injector nut and spray tip. With the cylinder head right side up and the injector tube free from dirt, proceed with the first reaming operation as follows:

a. Place a few drops of light cutting oil on the reamer flutes, then carefully position reamer J 22525-1 in the injector tube.

b. Turn the reamer in a clockwise direction (withdrawing the reamer frequently for removal of chips) until the lower shoulder of the reamer contacts the injector tube (Fig. 4). Clean out all of the chips.

2. Remove excess stock:

a. With the cylinder head bottom side up, insert the pilot of cutting tool J 5286-8 into the small hole of the injector tube.

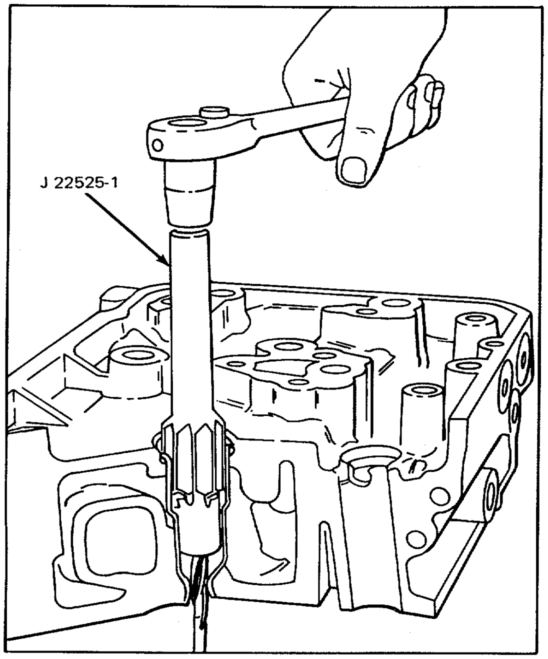


Figure 4. Reaming Injector Tube for Injector Body Nut and Spray Tip

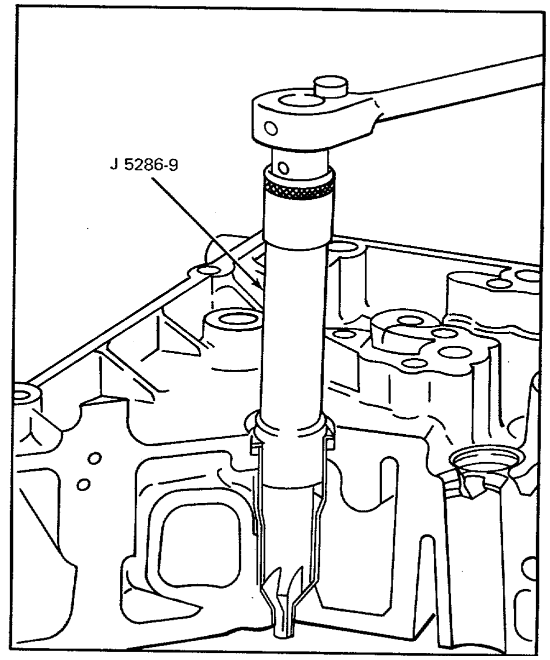


Figure 5. Reaming Injector Tube for Injector Nut

b. Place a few drops of cutting oil on the tool. Then, using a socket and a speed handle, remove the excess stock so that the lower end of the injector tube is from flush to 0.005 inch below the finished surface of the cylinder head.

3. Ream the bevel seat in the injector tube:

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip in the combustion chamber. Therefore, to determine the amount of stock that must be reamed from the bevel seat of the tube, refer to Fig. 6.

Install gage J 25521 in the injector tube. Zero the sled gage dial indicator J 22273 to the fire deck. Gage J 25521 should be flush to ±0.014 inch with the fire deck of the cylinder head (Fig. 7).

NOTE

Any fire deck resurfacing work must be done prior to final injector tube seat gaging. Refer to *Cylinder Head* for resurfacing instructions.

With the first reaming operation completed and the injector tube spotfaced, wash the interior of the injector tube with clean solvent and dry it

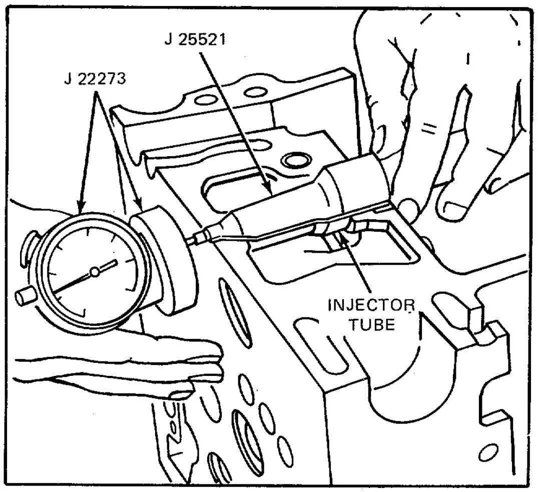


Figure 6. Measuring Relationship of Bevel Seat in Injector Tube to Cylinder Head Fire Deck

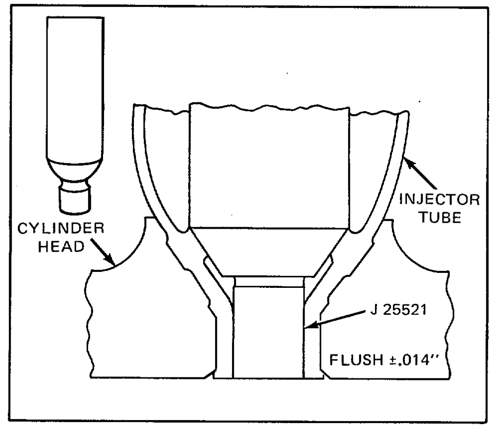


Figure 7. Measuring Relationship of Gage to Cylinder Head Fire Deck

with compressed air. Then perform the second reaming operation as follows:

a. Place a few drops of cutting oil on the bevel seat of the tube. Carefully lower reamer J 5286-9 into the injector tube until it contacts the bevel seat.

b. Make a trial cut by turning the reamer steadily without applying any downward force on the reamer. Remove the reamer, blow out the chips and look at the bevel seat to see what portion of the seat has been cut.

c. Proceed carefully with the reaming operation, withdrawing the reamer occasionally to observe the reaming progress.

d. Remove the chips from the injector tube and, using gage J 25521, continue the reaming operation until the shoulder of the spray tip is flush to ± 0.014 inch with the fire deck of the cylinder head as shown in Fig. 7. Then wash the interior of the injector tube with clean solvent and dry it with compressed air.

FUEL PUMP

The positive displacement gear-type fuel pump (Fig. 1) transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return manifold and fuel return line.

On the in-line engine, the fuel pump is mounted on the governor weight housing and is driven through a drive coupling by the governor weight shaft.

Certain engine applications use a high-capacity fuel pump with 3/8-inch-wide gears to increase fuel flow and reduce fuel spill temperature. The high-capacity fuel pump and the standard fuel pump with 1/4-inch-wide gears are not completely interchangeable; therefore, when replacing a standard pump with a high-capacity pump, the appropriate fuel lines and connections must be used.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining gear shaft alignment.

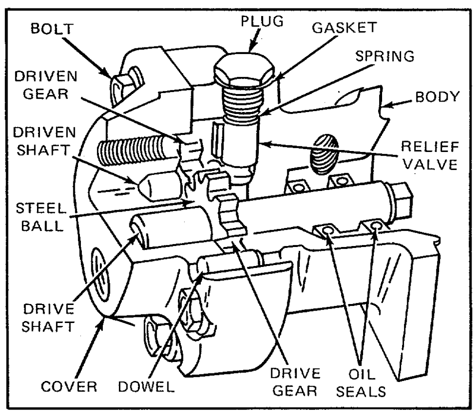


Figure 1. Typical Fuel Pump Assembly.

The mating surfaces of the pump body and cover are perfectly flat ground surfaces. No gasket is used between the cover and body since the pump clearances are set up on the basis of metal-to-metal contact. A very thin coat of sealant provides a seal against any minute irregularities in the mating surfaces. Cavities in the pump cover accommodate the ends of the drive and driven shafts.

The fuel pump body is recessed to provide running space for the pump gears (Fig. 2). Recesses are also provided at the inlet and outlet positions of the gears. The small hole A permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end and to eliminate the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through hole B and provides for relief of excess discharge pressures. Fuel reenters the inlet side of the pump through hole C when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through hole C. The cavity D provides escape for the fuel oil which is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body, and cover.

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the blower timing gear compartment (Fig. 1). The oil seals are installed with the lips of the seals facing toward the flanged end of the pump body. A small hole E (Fig. 2) serves as a vent passageway in the body, between the inner oil seal

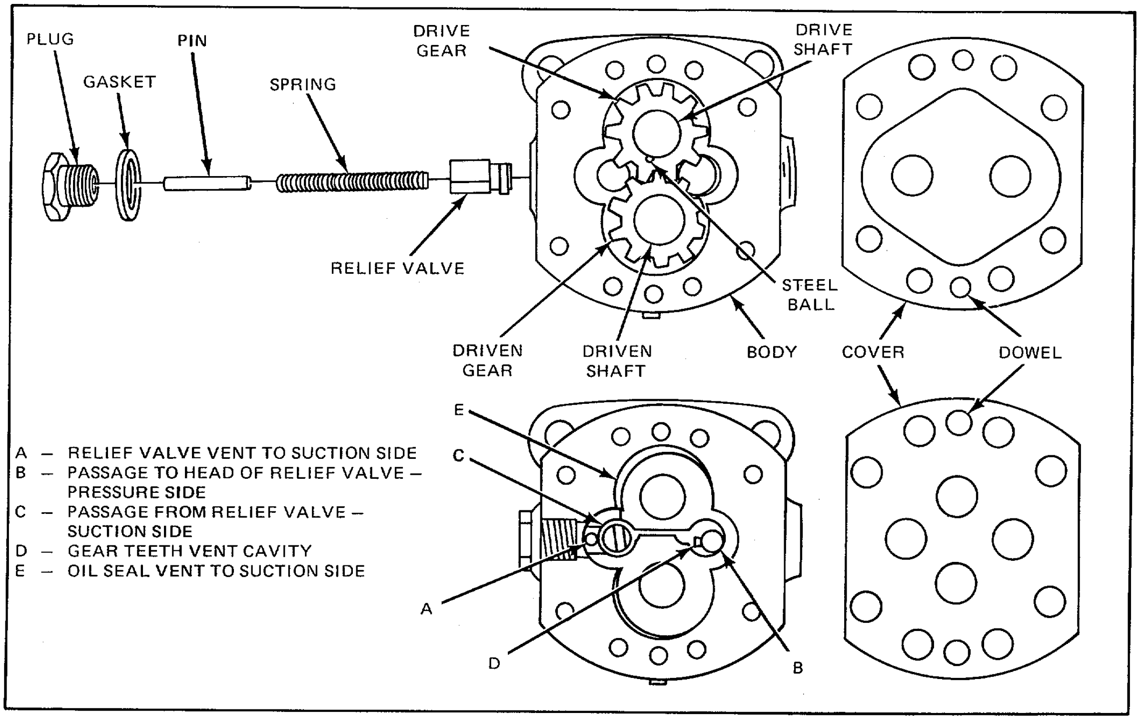


Figure 2. Fuel Pump Valving and Rotation (Right Hand Pump Shown).

and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal.

Some fuel oil seepage by the fuel pump seals can be expected, both with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump and/or new pump seals, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some seepage. Tapped holes in the pump body are provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel, therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals. The drive and driven gears are a line-to-line to a 0.001-inch press fit on their shafts. The drive gear is provided with a gear retaining ball to locate the gear on the shaft.

A spring-loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 65 psi (448 kPa).

Operation

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth which are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and, as the gear teeth mesh in the center of the pump, the fuel is forced out into the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 65 to 75 psi (448 to 517 kPa).

The fuel pump should maintain the fuel pressure at the fuel inlet manifold as shown in *Engine Operating Condition*.

Remove Fuel Pump

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.

2. Disconnect the drain tube, if used, from the fuel pump.

3. Remove the three pump attaching bolt and seal assemblies and withdraw the pump.

4. Check the drive coupling fork and, if broken or worn, replace it with a new coupling.

Disassemble Fuel Pump

With the fuel pump removed from the engine and mounted in holding fixture J 1508-10 as shown in Fig. 3, refer to Fig. 1 and 5 and disassemble the pump as follows:

1. Remove the eight cover bolts and withdraw the pump cover from the pump body. Use care not to damage the finished faces of the pump body and cover.

2. Withdraw the drive shaft, drive gear, and gear retaining ball as an assembly from the pump body.

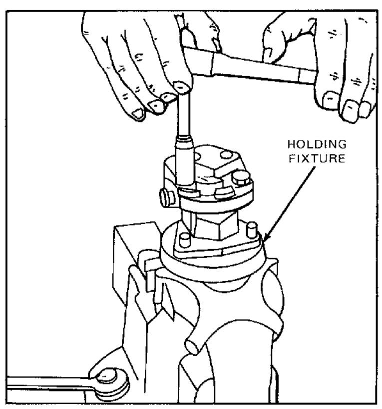


Figure 3. Removing Fuel Pump Cover

3. Press the drive shaft just far enough to remove the steel locking ball. Then invert the shaft and gear assembly and press the shaft from the gear. DO NOT misplace the steel ball. Do not press the squared end of the shaft through the gear as slight score marks will damage the oil seal contact surf ace.

4. Remove the driven shaft and gear as an assembly from the pump body. DO NOT remove the gear from the shaft. The driven gear and shaft are serviced only as an assembly.

5. Remove the relief valve plug and copper gasket.

6. Remove the valve spring, pin, and relief valve from the valve cavity in the pump body.

7. If the oil seals need replacing, remove them with oil seal remover J 1508-13 (Fig. 4). Clamp the pump body in a bench vise and tap the end of the tool with a hammer to remove the outer and inner seals.

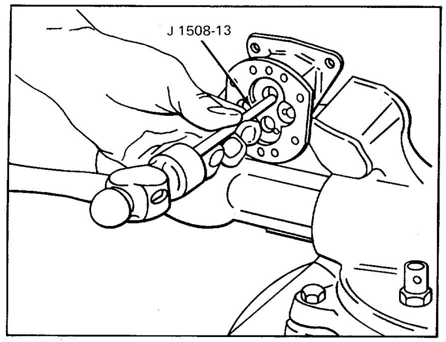


Figure 4. Removing Oil Seals

CAUTION

Observe the position of the oil seal lips before removing the old seals to permit installation of the new seals in the same position.

Inspection

Clean all of the parts in clean fuel oil and dry them with compressed air.

Oil seals, once removed from the pump body, must be discarded and replaced with new seals.

Check the pump gear teeth for scoring, chipping, or wear. Check the ball slot in the drive gear for wear. If necessary, replace the gear.

Inspect the drive and driven shafts for scoring or wear. Replace the shafts if necessary. The driven shaft is serviced as a gear and shaft assembly only.

The mating faces of the pump body and cover must be flat and smooth and fit tightly together. Any scratches or slight damage may result in pressure leaks. Also, check for wear at areas contacted by the gears and shafts. Replace the pump cover or body if necessary.

The relief valve must be free from score marks and burrs and fit its seat in the pump body. If the valve is scored and cannot be cleaned up with fine emery cloth or crocus cloth, it must be replaced.

Current standard fuel pumps (with 1/4-inch-wide gears) incorporate a 1/8 inch shorter pump body with three drain holes, a 1/8 inch shorter drive shaft and a cover with a 3/8 inch inlet opening. When replacing a former pump, a 3/8 x 1/4 inch reducing bushing is required for the inlet opening and the unused drain holes must be plugged.

Assemble Fuel Pump

Refer to Fig. 1, 2, and 5 and assemble the pump as follows:

1. Lubricate the lips of the oil seals with a light coat of vegetable shortening, then install the oil seals in the pump body as follows:

a. Place the inner oil seal on the pilot of installer handle J 1508-8 so that the lip of the seal will face toward the shoulder on the tool.

b. With the pump body supported on woodblocks (Fig. 6), insert the pilot of the installer handle in the pump body so the seal starts straight into the pump flange. Then drive the seal in until it bottoms.

c. Place the shorter end of adaptor J 1508-9 over the pilot and against the shoulder of the installer handle.

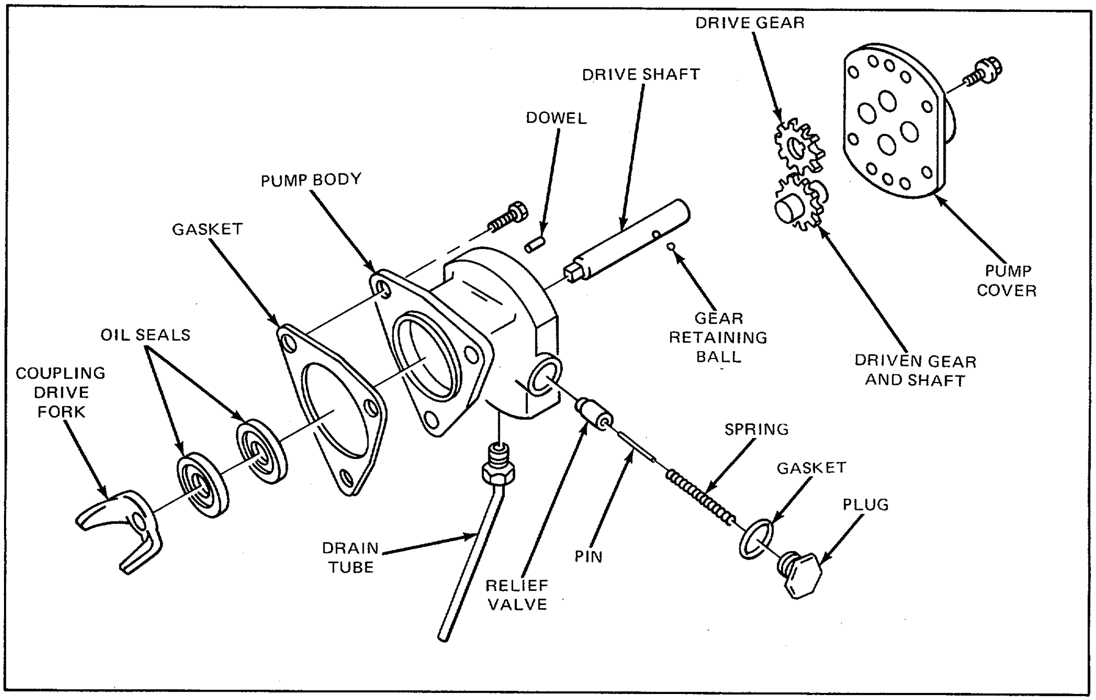


Figure 5. Fuel Pump Details and Relative Location of Parts (Right Hand Pump Shown)

Place the outer oil seal on the pilot of the installer handle with the lip of the seal facing the adaptor. Then insert the pilot of the installer handle into the pump body and drive the seal in (Fig. 7) until the shoulder of the adaptor contacts the pump body. The oil seals will be positioned so that the space between them will correspond with the drain holes located in the bottom of the pump body.

2. Clamp the pump body in a bench vise (equipped with soft jaws) with the valve cavity up. Lubricate the outside diameter of the valve and place it in the cavity with the hollow end up. Insert the spring inside of the valve and the pin inside of the spring. With a new gasket in place next to the head of the valve plug, place the plug over the spring and thread it into the pump body. Tighten the 1/2-20 plug to 18-22 lb ft (24-30 Nm) torque.

3. Install the pump drive gear over the end of the drive shaft which is not squared so the slot in the gear will face the plain end of the shaft. This operation is very important, otherwise fine score marks caused by pressing the gear into position from the square end of the shaft may cause rapid wear of the oil seals. Press the gear beyond the gear retaining ball detent. Then place the ball in the detent and press the gear back until the end of the slot contacts the ball.

4. Lubricate the pump shaft and insert the square end of the shaft into the opening at the gear side of the pump body and through the oil seals as shown in Fig. 8.

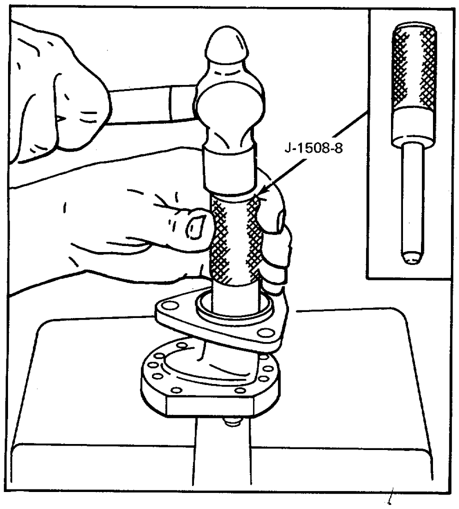


Figure 6. Installing Inner Oil Seal

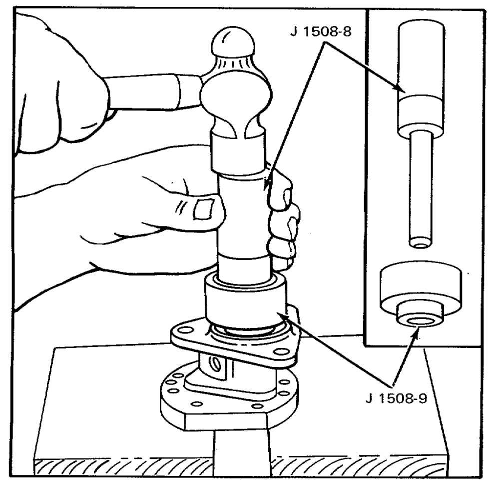


Figure 7. Installing Outer Oil Seal

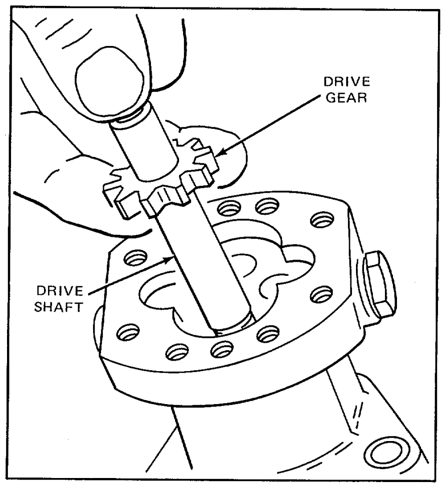


Figure 8. Installing Fuel Pump Drive Shaft and Gear Assembly

5. Place the driven shaft and gear assembly in the pump body.

CAUTION

The driven gear must be centered on the shaft to give proper end clearance. Also, the chamfered end of the gear teeth of the production gear must face the pump body. If a service replacement gear with a slot is used, the slot must face toward the pump cover.

6. Lubricate the gears and shafts with clean engine oil.

7. Apply a thin coat of quality sealant on the face of the pump cover outside of the gear pocket area. Then place the cover against the pump body with the two dowel pins in the cover entering the holes in the pump body. The cover can be installed in only one position over the two shafts.

CAUTION

The coating of sealant must be extremely thin since the pump clearances have been set up on the basis of metal-to-metal contact. Too much sealant could increase the clearances and affect the efficiency of the pump. Use care that sealant is not squeezed into the gear compartment, otherwise damage to the gears and shafts may result.

8. Secure the cover in place with eight bolts and lock washers, tightening the bolts alternately and evenly.

9. After assembly, rotate the pump shaft by hand to make certain that the parts rotate freely. If the shaft does not rotate freely, attempt to free it by tapping a corner of the pump.

10. Install 1/8-inch pipe plugs in the upper unused drain holes.

11. If the pump is not to be installed immediately, place plastic shipping plugs in the inlet and outlet openings to prevent dirt or other foreign material from entering the pump.

Install Fuel Pump

1. Affix a new gasket to the pump body mounting flange and locate the pump drive coupling over the square end of the fuel pump drive shaft.

2. Install the fuel pump on the engine and secure it with three nylon patch bolts.

NOTE

To provide improved sealing against leakage, nylon patch bolts are used in place of the former bolt and seal assemblies.

3. Connect the inlet and outlet fuel lines to the fuel pump.

4. Connect the fuel pump drain tube, if used, to the pump body.

5. If the fuel pump is replaced or rebuilt, prime the fuel system before starting the engine. This will prevent the possibility of pump seizure upon initial starting.

FUEL STRAINER AND FUEL FILTER

(Bolt-On Type)

A fuel strainer (primary) and fuel filter (secondary), Fig. 1, are used to remove impurities from the fuel. The fuel strainer is located between the fuel tank and the fuel pump. The replaceable density-type element is capable of filtering out particles of 30 microns (a micron is approximately 0.00004 inch). The fuel filter is installed between the fuel pump and the fuel inlet manifold. The replaceable paper-type element (Fig. 2) can remove particles as small as 10 microns.

CAUTION

A fuel tank of galvanized steel should never be used for fuel storage, as the fuel oil reacts chemically with the zinc coating to form powdery flakes which quickly clog the fuel filter and cause damage to the fuel pump and the fuel injectors.

The fuel strainer and fuel filter are essentially the same in construction and operation, and they will be treated as one in this section.

The filter and strainer, illustrated in Fig. 3 and 4, consist basically of a shell, a cover, and a replaceable filtering element. The assembly is made oil-tight by a shell gasket, a cover bolt, and a cover bolt gasket.

The central stud is a permanent part of the shell and, when the unit is assembled, extends up through the cover where the cover bolt holds the assembly together.

A filter element sets over the central stud inside the shell and is centered in the shell by the stud.

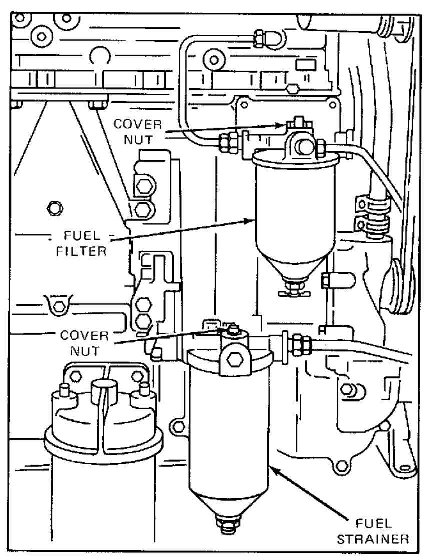


Figure 1. Typical Fuel Strainer and Fuel Filter Mounting

The former and current cover assemblies are visibly different by a cast letter P (primary) that has been added to the top of the strainer cover and the letter S (secondary) that has been added to the top of the filter cover.

Operation

Since the fuel strainer is between the fuel supply tank and the fuel pump, it functions under suction. The filter, placed between the fuel pump and the fuel inlet manifold in the cylinder head, operates under pressure. Fuel enters through the inlet passage in the

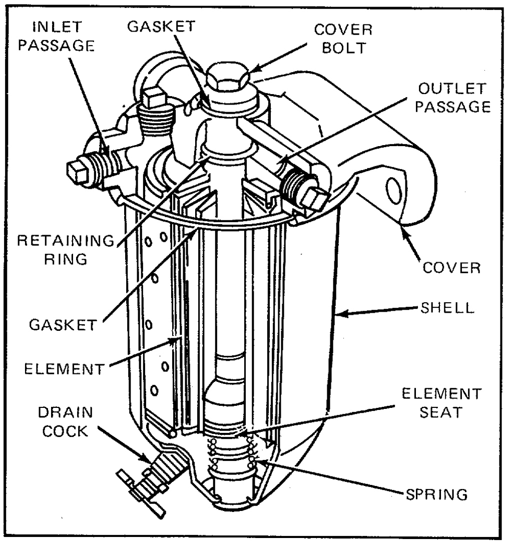


Figure 2. Fuel Filter Assembly.

cover and into the shell surrounding the filter element. Pressure or suction created by the pump causes the fuel to flow through the filter element where dirt particles are removed. Clean fuel flows to the interior of the filter element, up through the central passage in the cover, into the outlet passage, and then to the fuel inlet manifold in the cylinder head.

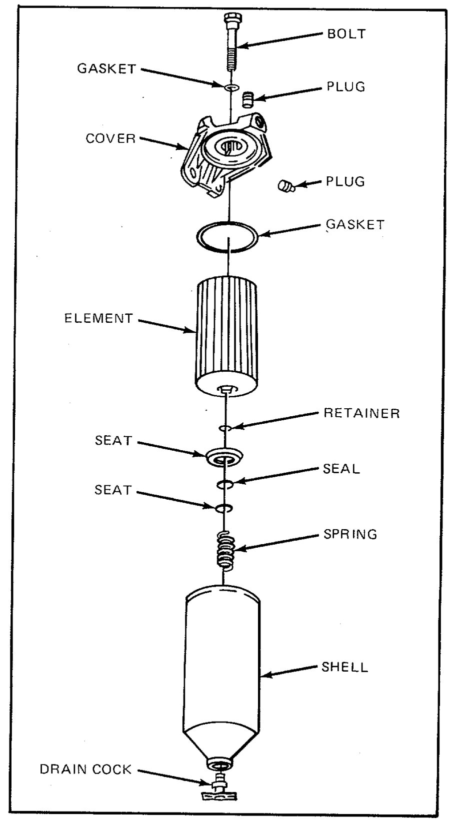


Figure 3. Fuel Strainer Details and Relative Location of Parts.

If engine operation is erratic, indicating shortage of fuel or flow obstructions, refer to *Troubleshooting* for corrective measures.

Replace Fuel Strainer or Filter Element

The procedure for replacing an element is the same for the fuel strainer or fuel filter. Refer to Fig. 3 and 4 and replace the element as follows:

CAUTION

Only filter elements designed for fuel oil filtration should be used to filter the fuel.

1. With the engine stopped, place a container under the strainer or filter

and open the draincock. Loosen the cover bolt just enough to allow the fuel oil to drain out freely. Then close the draincock.

CAUTION

The wiring harness, starting motor or other electrical equipment must be shielded during the filter change, since fuel oil can permanently damage the electrical insulation.

2. While supporting the shell, unscrew the cover bolt and remove the shell and element.

3. Remove and discard the filter element, shell gasket, and the cover bolt gasket. Wash the shell thoroughly with clean fuel oil and dry it with compressed air.

4. Examine the element seat and the retaining ring to make sure they have not slipped out of place. Check the spring by pressing on the element seat. When released, the seat must return against the retaining ring.

NOTE

The element seat, spring, washer, and seal cannot be removed from the strainer shell. If necessary, the shell assembly must be replaced. However, the components of the filter shell are serviced. Examine the filter retainer seal for cracks or hardening. If necessary, replace the seal.

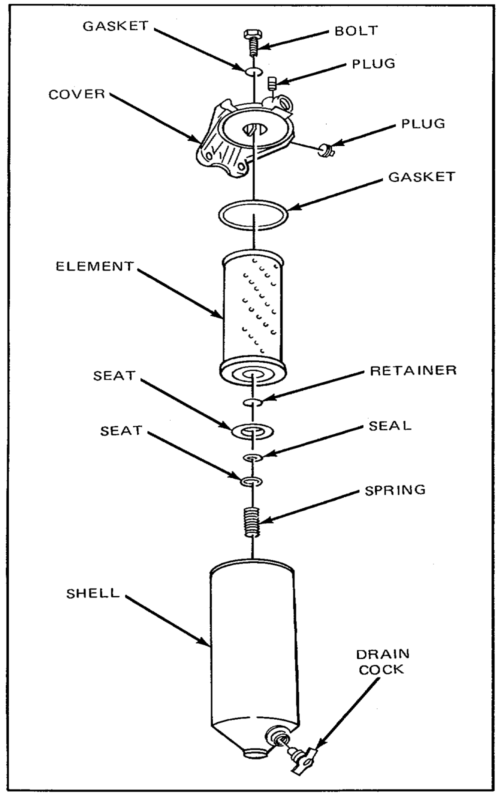


Figure 4. Fuel Filter Details and Relative Location of Parts

5. Place a new element over the center stud and push it down against the element seat. Make sure the draincock is closed, then fill the shell about two-thirds full with clean fuel oil.

NOTE

Thoroughly soak the density-type strainer element in clean fuel oil before installing it. This will expel any air entrapped in the element and is conducive to a faster initial start.

6. Place a new shell gasket in the recess of the shell; also place a new gasket on the cover bolt.

7. Place the shell and element in position under the cover. Then thread the cover bolt into the center stud.

8. With the shell and the gasket properly positioned, tighten the cover bolt just enough to prevent fuel leakage.

9. Remove the pipe plug at the top of the cover and complete filling of the shell with fuel. Fuel system primer J 5956 may be used to prime the entire fuel system.

10. Start the engine and check the fuel system for leaks.

FUEL STRAINER AND FUEL FILTER

(Spin-On Type)

A spin-on type fuel strainer and fuel filter (Fig. 5) is used on certain engines. The spin-on filter cartridge consists of a shell, element and gasket combined into a unitized replacement assembly (Fig. 6). No separate springs or seats are required to support the filters.

The filter covers incorporate a threaded sleeve to accept the spin-on filter cartridges. The word "Primary" is cast on the fuel strainer cover and the word "Secondary" is cast on the fuel filter cover for identification.

No draincocks are provided on the spin-on filters. Where water is a problem, it is recommended that a water separator be installed. Otherwise, residue may be drained by removing and invert- ing the filter. Refill the filter with clean fuel oil before reinstalling it.

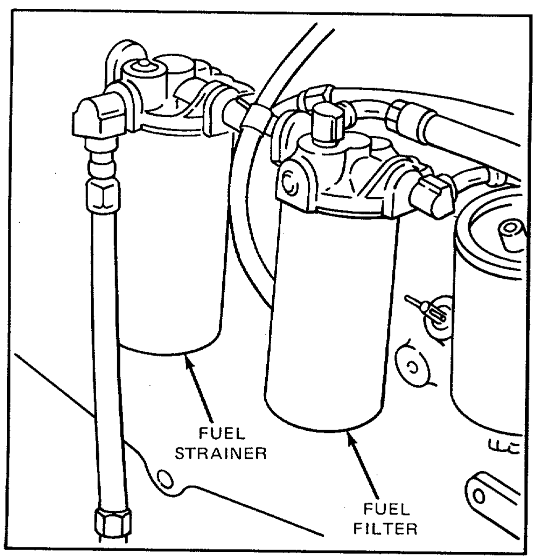


Figure 5. Typical Spin-On Type Fuel Strainer and Fuel Filter Mounting.

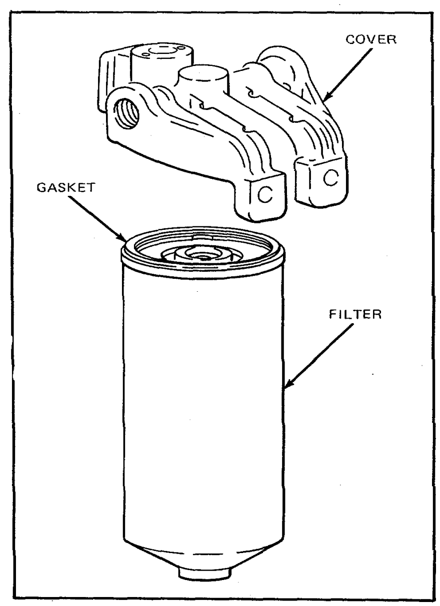


Figure 6. Spin-On Filter Details and Relative Location on Parts.

Filter Replacement

A 1-inch-diameter twelve-point nut on the bottom of the filter is provided to facilitate removal and installation.

Replace the filter as follows:

1. Unscrew the filter or strainer and discard it.

2. Fill a new filter replacement cartridge about two-thirds full with clean fuel oil. Coat the seal gasket lightly with clean fuel oil.

3. Install the new filter assembly and tighten it to one-half of a turn beyond gasket contact.

4. Start the engine and check for leaks.

MECHANICAL GOVERNORS

Horsepower requirements on an engine may vary due to fluctuating loads. Therefore, some method must be provided to control the amount of fuel required to hold the engine speed reasonably constant during load fluctuations. To accomplish this control, a governor is introduced in the linkage between the throttle control and the fuel injectors.

Engines subjected to varying load conditions that require an automatic fuel compensation to maintain a near constant engine speed, which may be changed manually by the operator, are equipped with a variable speed mechanical governor.

Check Governor Operation

Governor difficulties are usually indicated by speed variations of the engine. However, it does not necessarily mean that all such speed fluctuations are caused by the governor. Therefore, when improper speed variations are present, check the engine as follows:

1. Make sure the speed changes are not the result of excessive load fluctuations.

2. Check the engine to be sure that all of the cylinders are firing properly (refer to *Troubleshooting*). If any cylinder is not firing properly, remove the injector, test it and, if necessary, recondition it as outlined in *Fuel Injector*.

3. Check for bind that may exist in the governor operating mechanism or in the linkage between the governor and the injector control tube.

With the fuel rod connected to the injector control tube lever, the mechanism should be free from bind throughout the entire travel of the injector racks. If friction exists in the mechanism, it may be located and corrected as follows:

1. If an injector rack sticks or moves too hard, it may be due to the injector holddown clamp being too tight or improperly positioned. To correct this condition, loosen the injector clamp, reposition it and tighten the clamp bolt to 20-25 lb ft (27-34 Nm) torque.

2. An injector which is not functioning properly may have a defective plunger and bushing or a bent injector rack. Recondition a faulty injector as outlined in *Fuel Injector*.

3. An injector rack may bind as the result of an improperly positioned rack control lever. Loosen the rack control lever adjusting screws. If this relieves the bind, relocate the lever on the control tube and position the rack as outlined in *Engine Tuneup*.

4. The injector control tube may bind in its support brackets, thus preventing free movement of the injector racks to their no-fuel position due to tension of the return spring. This condition may be corrected by loosening and realigning the control tube supporting brackets. If the control tube support brackets were loosened, realigned and tightened, the injector racks must be repositioned as outlined in *Engine Tuneup*.

5. A bent injector control tube return spring may cause friction in the operation of the injector control tube. If the spring has been bent or otherwise distorted, install a new spring.

6. Check for bind at the pin which connects the fuel rod to the injector control tube lever; replace the pin, if necessary.

If, after making these checks, the governor fails to control the engine properly, remove and recondition the governor.

VARIABLE SPEED MECHANICAL GOVERNOR

The variable speed open linkage governor (Fig. 1) performs the following functions:

1. Controls the engine idle speed.

2. Limits the maximum no-load speed.

3. Holds the engine at any constant speed, between idle and maximum, as desired by the operator.

The single-weight governor is mounted on the rear end plate of the engine and is driven by a gear that extends through the end plate and meshes with either the camshaft gear or the balance shaft gear, depending upon the engine model.

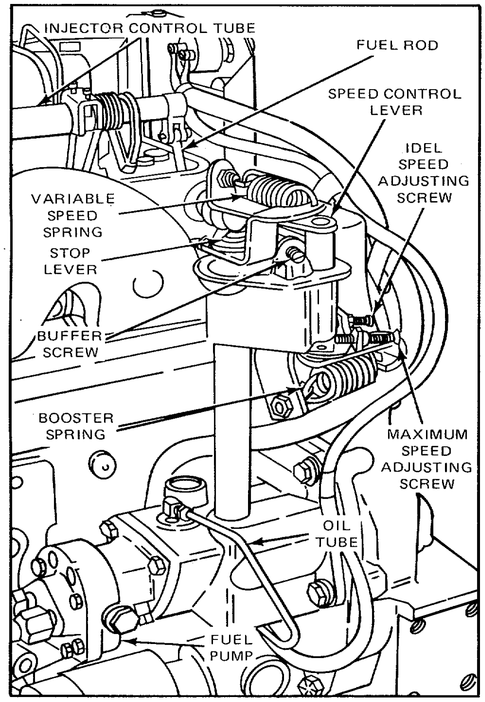


Figure 1. Variable Speed Open Linkage Governor Mounted on Engine

Operation

Two manual controls are provided on the governor: a stop lever and a speed control lever. In its normal position, the stop lever holds the fuel injector racks near the full-fuel position. When the engine is started, the governor moves the injector racks toward the idle speed position. The engine speed is then controlled manually by moving the speed control lever.

The centrifugal force of the revolving governor weights is converted into linear motion which is transmitted through the riser and the operating shaft to the operating shaft lever. Movement of this lever is transmitted to the stop lever which changes the fuel setting of the injector racks, since the fuel rod is connected between the stop lever and the injector control tube.

The centrifugal force of the governor weights is opposed by the variable speed spring which is fastened to the end of the operating shaft lever. Load changes or movement of the speed control lever momentarily creates an unbalanced force between the revolving weights and the tension on the spring. When the forces reach a balanced condition again, the engine speed will be stabilized for the new speed setting or new load.

To stop the engine, the speed control lever is moved to the idle-speed position and the stop lever is moved to the no-fuel position and held there until the engine stops.

Adjustment of the governor is covered in *Governor and Injection Rack Control Adjustment.*

Lubrication

The governor is lubricated by oil splashed from the engine gear train. The oil passes through the governor weight housing to the shaft and weight assembly. The revolving weights distribute the oil to the various moving parts of the governor. The surplus oil drains back to the engine crankcase through holes in the governor bearing retainer.

The clearance between the riser tube and the weight shaft has been reduced with the use of current governor assemblies. To ensure adequate lubrication of the riser tube, an oil tube has been added between the oil gallery in the cylinder block and the top of the weight housing to supply oil under pressure.

Remove Governor From Engine

Check the operation of the governor as outlined in *Mechanical Governors* before removing it from the engine. If the governor fails to control the engine properly after performing these checks, it should be removed and reconditioned.

Refer to Fig. 1 and remove the governor as follows:

1. Disconnect the fuel rod from the stop lever.

2. Disconnect the throttle-control rod from the speed-control lever.

3. Disconnect the fuel lines and remove the fuel pump from the governor weight housing.

4. Remove the governor lubricating oil tube, if used.

5. Withdraw the five bolts from the weight housing and the two bolts from the control housing; then, remove the governor and gasket from the engine.

Disassemble Weight Housing

1. Remove the governor drive gear retaining nut. Then remove the gear, key, and spacer from the shaft.

2. Remove the small flathead screw (Fig. 3) which holds the bearing retainer in place.

3. Turn the bearing retainer until the large opening is centered over the fork on the governor operating shaft (Fig. 2).

4. Lift up on the weight shaft to provide clearance for a 5/16-inch electrician's socket wrench. Then remove the two retaining screws and washers and withdraw the governor operating fork.

5. Remove the shaft and weight assembly from the governor weight housing.

6. Inspect the bushing in the weight housing. If the bushing is worn or pitted, press it out of the housing and install a new bushing.

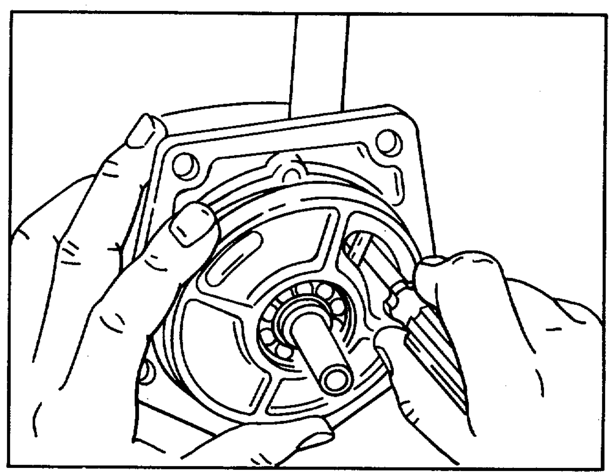


Figure 2. Removing or Installing Operating Shaft Fork

Disassemble Weight Shaft Assembly

1. Press the bearing (Fig. 3) from the weight shaft.

2. If necessary, remove the snapring and press the bearing from the retainer.

3. Remove the weight pin retainers and drive the pins out of the carrier and weights. Remove the weights.

NOTE

The weight pinhole in the carrier is larger at the side where the pin retainers are located.

4. Slide the riser and bearing assembly from the shaft. Do not attempt to remove the bearing since the riser and bearing are serviced only as an assembly.

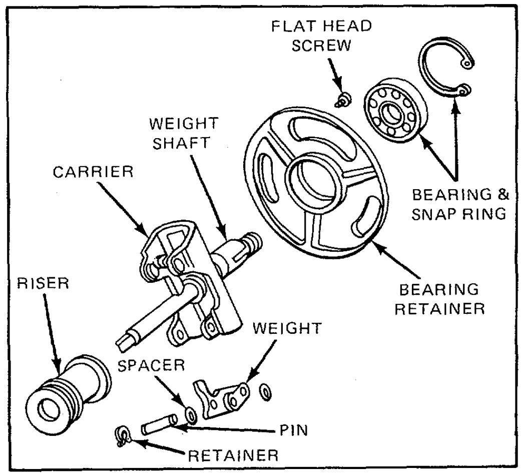


Figure 3. Governor Weight Details and Relative Location of Parts.

Disassemble Control Housing

1. Remove the outer nut on the variable speed spring eyebolt. Then remove the spring and eyebolt.

2. Pry the plug from the bottom of the weight housing.

3. Remove the snapring from the lower end of the operating shaft and tap the shaft and lever assembly out of the control housing.

4. Remove the snapring and press the lower operating shaft bearing out of the weight housing.

5. Withdraw the outer nut and remove the booster spring and eyebolt.

6. Drive the pin from the speed-control lever and remove the lever from the shaft.

7. Slide the shaft and booster spring bracket from the housing.

8. Remove the buffer screw.

9. Disengage the small spring between the operating-shaft lever and the stop lever.

10. Remove the retaining ring and washer and lift the stop lever from the operating shaft.

11. Drive the pin from the operating-shaft lever and remove the lever from the shaft.

12. Slide the bearing shield from the operating shaft.

13. Press the bearing from the operating shaft.

Inspection

Clean all of the parts (except the shielded upper operating-shaft bearing) with fuel oil and dry them with compressed air.

Revolve the ball bearings slowly by hand. Replace bearings which indicate rough or tight spots. Also replace bearings which are corroded or pitted.

The lower governor drive components have been revised to reduce the clearance between the riser and the weight shaft. With this change, additional lubrication is provided to the governor by an oil tube connected between the oil gallery in the cylinder block and the governor weight housing. When replacing the riser assembly, shaft and carrier assembly, or the complete governor assembly, the new oil tube must be installed to provide adequate lubrication.

Examine the riser-thrust bearing for excessive wear, flat spots, or corrosion. If any of these conditions exist, install a new riser and bearing assembly.

Inspect the weight carrier, weights, and retaining pins for wear.

Examine the fuel pump drive end of the weight shaft. Replace the shaft if the end is worn or rounded.

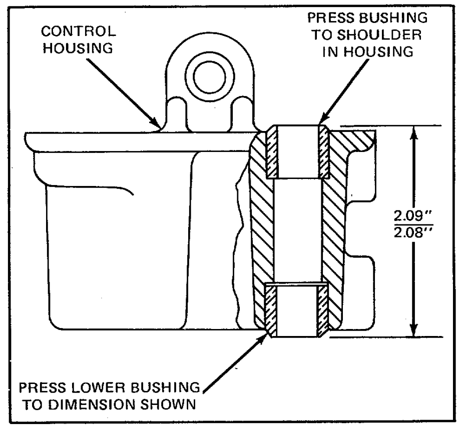


Figure 4. Bushings in Control Housing.

Inspect the bushings in the control housing. If they are worn, drive the bushings out and install new ones.

Press the upper bushing in until it contacts the shoulder in the housing. Press the lower bushing to the dimension shown in Fig. 4.

Assemble Control Housing

Refer to Fig. 5 and assemble the control housing as follows:

1. Start the upper bearing, number side up, on the governor operating shaft. Support the shaft on the bed of an arbor press. Place a sleeve against the inner race and press the bearing against the shoulder on the shaft.

2. Slide the bearing shield on the shaft.

3. Place the operating-shaft lever on the shaft and align the retaining pinholes. Then drive the retaining pin in place to secure the lever to the shaft.

4. Place the stop lever on the operating shaft and secure it in place with the washer and retaining ring. Then hook the small spring to the stop lever and operating-shaft lever.

5. Install the lower operating-shaft bearing, number side out, in the weight housing. Install the snapring to secure the bearing. Lubricate the bearing with engine oil.

6. Insert the operating shaft and lever assembly in the control housing. Tap the shaft into the lower bearing and install a snapring on the end of the shaft.

7. Apply a good quality sealant around the edge of the plug and tap it in place in the weight housing.

8. Place the fork against the operating shaft, with the two cam faces of the fork facing away from the governor weights. Thread the fork-attaching screws in approximately two or three turns. The screws are tightened after the weight and shaft assembly is installed.

9. Install the booster-spring bracket.

10. Slide the speed-control shaft assembly in the control housing. Then place the speed-control lever on the shaft and tap the pin in place to secure the lever.

11. Install the booster spring and the variable speed spring.

12. Install the buffer screw.

Assemble Weight and Shaft Assembly

1. If the weight carrier was removed from the weight shaft, press the carrier on the shaft so as to allow a clearance of 0.001 to 0.006 inch between the shaft shoulder and the rear face of the weight carrier.

2. Press the bearing (Fig. 3) in the retainer (press on the outer race). Then install the snapring with the flat side of the ring facing the bearing.

3. Press the bearing and retainer assembly on the shaft until the bearing contacts the shoulder on the shaft.

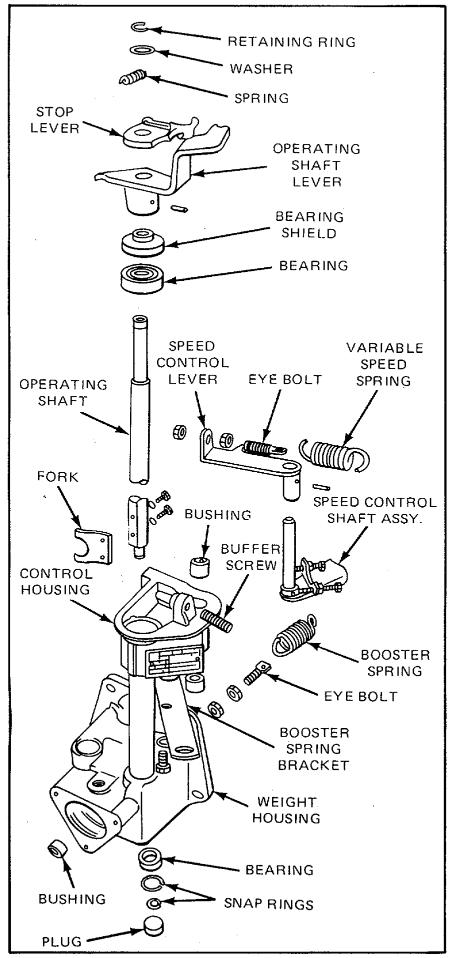


Figure 5. Governor Housing Details and Relative Location of Parts.

CAUTION

Press on the inner race of the bearing.

4. Lubricate the shaft with clean engine oil. Then slide the riser and bearing assembly on the shaft.

5. Secure the weights to the carrier as follows:

a. Position one of the weights, with a spacer on each side, in the carrier.

b. Insert the serrated end of the weight pin through the larger opening in the carrier and through the weight and spacers. Then drive the pin into the smaller opening in the carrier.

c. Install a retainer in the groove of the pin.

d. Install the second weight in the same manner.

6. Slide the shaft and weight assembly into the weight housing, with the riser bearing positioned behind the operating fork.

7. Turn the bearing retainer until the large opening is over the fork on the operating shaft. Then tighten the two fork-attaching screws with a 5/16- inch electrician's socket wrench.

8. Turn the bearing retainer until the counterbored notch above the large opening in the retainer and the tapped hole in the housing are aligned. Secure the bearing retainer to the housing with a flathead screw.

9. Place the governor drive-gear spacer on the shaft. Install the key and start the gear on the shaft.

10. Tap the gear until the gear and spacer contact the inner race of the weight shaft bearing.

11. Install the gear retaining nut and tighten it to 125-135 lb ft torque.

Install Governor

Refer to Fig. 1 and install the governor as follows:

1. Attach a new gasket to the governor weight housing.

2. Position the governor against the engine rear end plate. The teeth on the governor drive gear must mesh with the teeth on the camshaft gear or balance-shaft gear.

3. Install the three 12-point head bolts with copper washers in the governor weight housing next to the cylinder block. Install the two remaining bolts with steel washers and lock washers. Tighten the bolts to 35 lb ft torque.

4. Install the two governor control housing attaching bolts and lock washers. Tighten the bolts to 35 lb ft torque.

5. Attach the fuel rod to the stud on the stop lever.

6. Install the fuel pump and fuel lines.

7. If required, install the governor lubricating oil tube and fittings.

8. Perform an engine tuneup as out-lined in *Engine Tuneup*.

FUEL INJECTOR CONTROL TUBE

The fuel injector control-tube assembly (Fig. 1) is mounted on the cylinder head and consists of a control tube, injector rack-control levers, a return spring, and injector control-tube lever mounted in two bracket and bearing assemblies attached to the cylinder head.

The injector rack-control levers connect with the fuel injector control racks and are held in position on the control tube with two adjusting screws. The return spring enables the rack levers to return to the no-fuel position. The injector control-tube lever is pinned to the end of the control tube and connects with the fuel rod which connects with the engine governor. Refer to *Engine Tuneup* for positioning of the injector rack-control levers.

Certain engines use a spring-loaded injector control-tube assembly (Fig. 2), similar to the above except it has a yield spring at each injector rack- control lever and only one screw and lock nut to keep each injector rack properly positioned. This enables an engine to be brought to a lesser fuel position if there is an inoperative fuel injector rack, whereas with the non-spring loaded two screw injector control tube this could not be done. The above also permits the use of an air inlet housing with no emergency air shut-off valve as is required in some applications.

NOTE

> Do not replace the spring-loaded fuel injector control tube and lever assembly with the two screw design control tube assembly without including an air inlet housing that incorporates an emergency air shut-off valve. However, when the spring-loaded fuel injector control tube and lever assembly is installed on an engine and the emergency shutdown mechanism is removed from the air inlet housing, the shaft holes at each end of the housing must be plugged. Ream the shaft holes to 0.6290 inch and install a 5/8-inch cup plug at each end of the housing.

Engine shutdown (normal or emergency) is accomplished on the spring-loaded fuel injector control tube (one screw design) by pulling the governor shutdown lever to the no-fuel position. With the two screw design injector control tube and lever assembly, emergency engine shutdown is accomplished by tripping the air shut-off valve in the air inlet housing. Normal shutdown is accomplished by pulling the governor shutdown lever to the no-fuel position. Adjustment of the single screw and lock nut on each injector rack-control lever can be performed the same as for the two screw design rack-control lever as outlined in *Engine Tuneup*.

Remove Injector Control Tube

1. Remove the cotter pin and clevis pin connecting the fuel rod to the injector tube-control lever.

2. Remove the two attaching bolts and lock washers at each bracket. Disengage the rack levers from the injector control racks and lift the control tube assembly from the cylinder head.

Disassemble Injector Control Tube

The injector control tube, one mounting bracket, a spacer, and injector control-tube lever are available as a service assembly. When any part of this assembly needs replacing, it is recommended the complete service assembly be replaced. Therefore, the

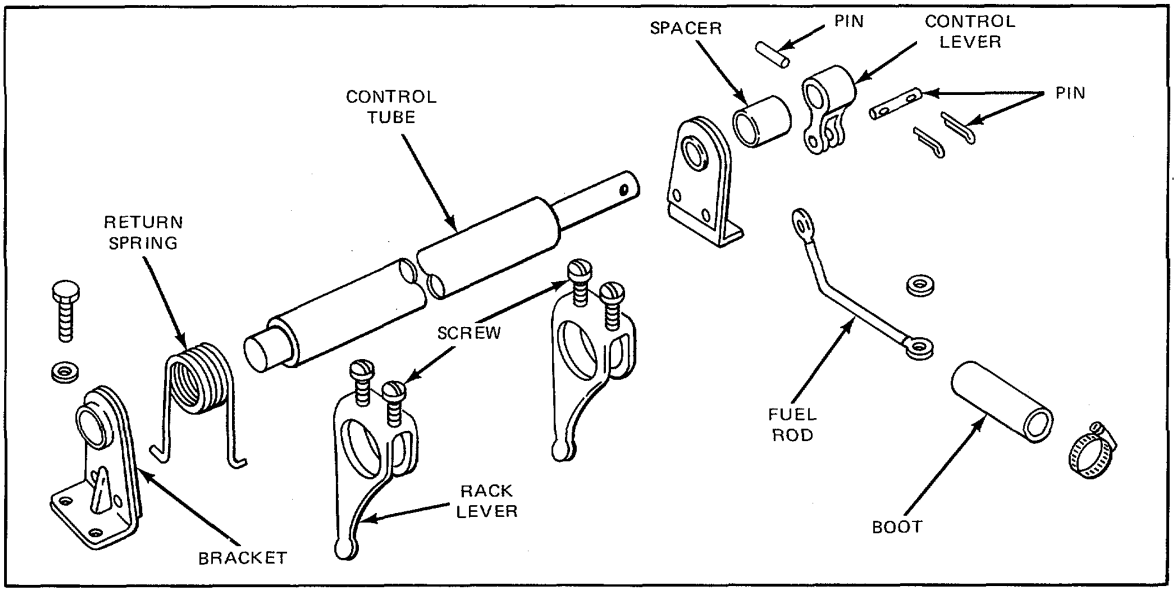


Figure 1. Injector Control Tube Assembly (Non-Spring Loaded-In-line Engine)

disassembly and assembly procedure for these items is not included in the following:

1. Remove the bracket from the injector control tube.

2. Loosen the adjusting screws or adjusting screw and lock nut at each injector rack-control lever.

3. With the spring-loaded injector control tube, disconnect the yield springs at each rack lever, then roll the yield springs out of the slots and notch of the control tube.

4. Disconnect the return spring from the bracket and front or rear rack lever.

5. Then remove the yield springs and/or return spring and rack levers from the control tube.

Inspection

Wash all of the injector control tube parts in clean fuel oil and dry them with compressed air.

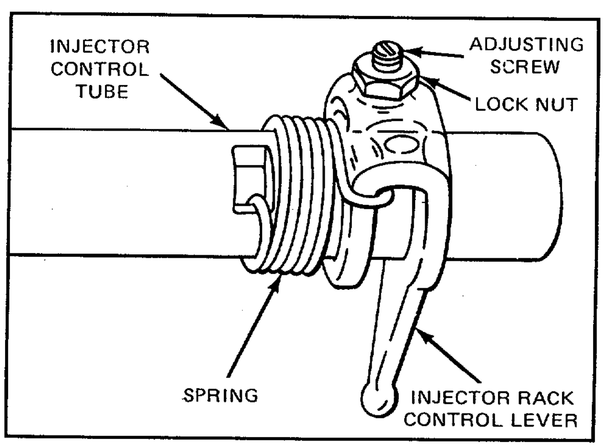


Figure 2. Injector Control Tube and Rack Lever (Spring-Loaded)

Examine the control tube, control lever, control tube rack-control levers and brackets for excessive wear, cracks or damage and replace them if necessary. The bearing in the bracket is not serviced separately. Examine the yield springs and/or return spring and replace them if worn or fractured.

Assemble Injector Control Tube

With all of the parts cleaned and inspected and the necessary new parts on hand, refer to Fig. 1 or 2 and assemble as follows:

1. On the two screw design injector control tube, install the rack-control levers on the control tube, with the levers facing the front bracket position. Turn the adjusting screws into the slots in the control tube far enough to position the levers.

2. On the one screw and lock nut design injector control tube, install the rack-control levers with the levers facing the front bracket position and the R.H. helix yield springs. Then install the odd (L.H. helix) yield spring and rack-control lever with the lever facing the front bracket position.

3. Attach the curled end of the yield springs to the rack-control levers and roll the springs into the notch (odd yield spring) and the slots (R.H. helix yield springs) in the control tube. Then turn the adjusting screws and lock nuts into the notch and slots far enough to position the levers on the control tube.

4. On both designs, install the control tube return spring and front bracket on the control tube. Attach the curled end of the return spring to the rack-control lever and the extended end of the spring behind the front bracket.

Install Injector Control Tube

1. Engage the injector rack-control levers with the injector control racks and place the brackets over the mount ing holes on the cylinder head.

2. Install the two 1/4-20 x 5/8- inch-long bolts and lock washers at each bracket to attach the injector control-tube assembly to the cylinder head. Tighten the bolts to 10-12 lb ft (14-16 Nm) torque.

3. Check the control tube to be sure it is free in the brackets. Tap the control tube lightly to align the bearings in the bracket, if necessary.

4. Connect the fuel rod to the injector tube-control lever with a clevis pin and a new cotter pin.

5. Refer to *Engine Tuneup* and position the injector rack control levers.

CAUTION

Be sure the injector rack- control levers can be placed in a no-fuel position before restarting the engine.

WARNING

Loss of shut down control could result in a runaway engine which could cause personal injury.

FUEL SYSTEM

SHOP NOTES - TROUBLESHOOTING

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

INJECTOR CALIBRATOR READINGS

Several factors affect the injector calibrator-output readings. The four major items are:

1. Operator Errors: If the column of liquid in the vial is read at the top of the meniscus instead of at the bottom, a variation of 1 or 2 points will result. Refer to Fig. 1.
2. Air In Lines: This can be caused by starting a test before the air is purged from the injector and lines, or from an air leak on the vacuum side of the pump.
3. Counter Improperly Set: The counter should be set to divert the injector output at 1000 strokes, but must be reset for 1200 strokes to check 35 and 40 cu. mm injectors. It is possible that in returning to the 1000 stroke setting, an error could be made.

This should not be confused with counter overrun that will vary from 2 to 6 digits, depending upon internal friction. The fuel diversion is accomplished electrically and will occur at 1000 strokes (if properly set) although the counter may overrun several digits.

4. Test Oil: A special test oil is supplied with the calibrator and should always be used. If regular diesel fuel oil (or any other liquid) is used, variations are usually noted because of the effect of the oil on the solenoid valve and other parts.

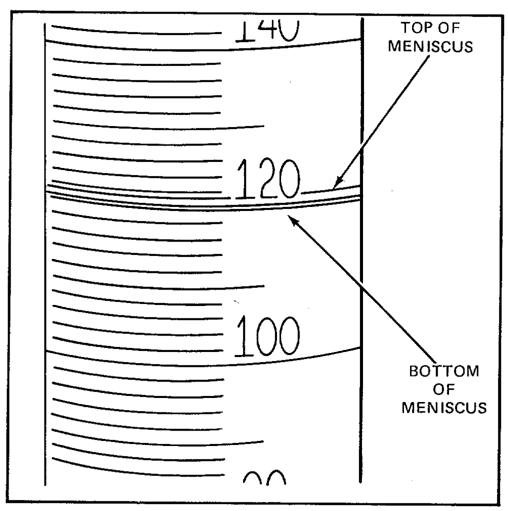


Figure 1. Checking Fuel Output

The fuel oil introduced into the test oil when the fuel injector is placed in the calibrator for a calibration check contaminates the test oil. Therefore, it is important that the test oil and test oil filter be changed every six months, or sooner if required. In addition, other malfunctions such as a slipping drive belt, low level of test oil, a clogged filter, a defective pump or leaking line connections could cause bad readings. A frequent check should be made for any of these telltale conditions.

CHECKING INJECTOR TESTER J 23010 OR J 9787

The injector tester J 23010 or J 9787 shoul4 be checked monthly to be sure that it is operating properly. The following check can be made very quickly using test block J 9787-49.

Fill the supply tank in the injector tester with clean injector test oil J 26400. Open the valve in the fuel supply line. Place the test block on the injector locating plate and secure the block in place with the fuel inlet connector clamp. Operate the pump handle until all of the air is out of the test block, then clamp the fuel outlet connector onto the test block. Break the connection at the gage and operate the pump handle until all of the air bubbles in the fuel system disappear. Tighten the connection at the gage. Operate the pump handle to pressurize the tester fuel system to 2400-2500 psi (16 536-17 225 kPa). Close the valve on the fuel supply line. After a slight initial drop, the pressure should remain steady. This indicates that the injector tester is operating properly. Open the fuel valve and remove the test block.

If there is a leak in the tester fuel system, it will be indicated by a drop in pressure. The leak must be located, corrected and the tester rechecked before checking an injector. Occasionally dirt will get into the pump check valve in the tester, resulting in internal pump valve leakage and the inability to build up pressure in the tester fuel system. Pump valve leakage must be corrected before an injector can be properly tested.

When the above occurs, loosen the fuel inlet connector clamp and operate the tester pump handle in an attempt to purge the dirt from the pump check valve. A few quick strokes of the pump handle will usually correct a dirt condition. Otherwise, the pump check valve must be removed, lapped and cleaned, or replaced (J 9787). The pump check valve in J 23010 must be replaced.

If an injector tester supply or gage line is damaged or broken, install a new replacement line (available from the tester manufacturer). Do not shorten the old lines or the volume of test oil will be altered sufficiently to give an inaccurate valve holding pressure test.

If it is suspected that the lines have been altered, i.e. by shortening or replacing with a longer line, check the accuracy of the tester with a master injector on which the pressure holding time is known. If the pressure holding time does not agree with that recorded for the master injector, replace the lines.

REFINISH LAPPING BLOCKS

As the continued use of the lapping blocks will cause worn or low spots to develop in their lapping surfaces, they should be refinished from time to time.

It is good practice, where considerable lapping work is done, to devote some time each day to refinishing the blocks. The quality of the finished work depends to a great degree on the condition of the lapping surfaces of the blocks.

To refinish the blocks, spread some 600-grit lapping powder of good quality on one of the blocks. Place another block on top of this one and work the blocks together as shown in Fig. 2.

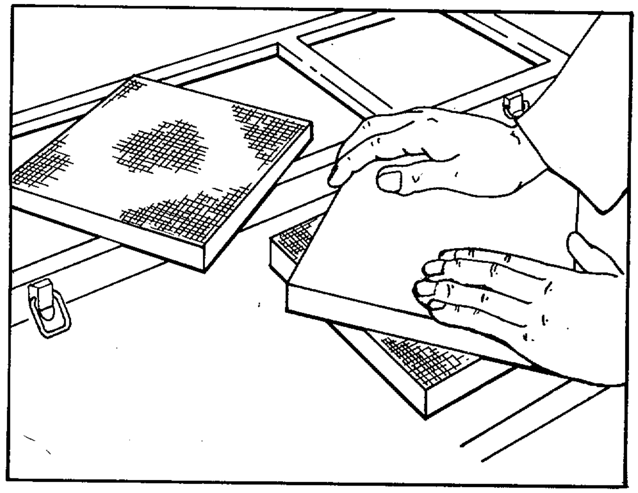


Figure 2. Refinishing Lapping Blocks

Alternate the blocks from time to time. For example, assuming the blocks are numbered 1, 2, and 3, work 1 and 2 together, then 1 and 3, and finish by working 2 and 3 together. Continue this procedure until all of the blocks are perfectly flat and free of imperfections

Imperfections are evident when the blocks are clean and held under a strong light. The blocks are satisfactory when the entire surface is a solid dark grey. Bright or exceptionally dark spots indicate defects and additional lapping is required.

After the surfaces have been finished, remove the powder by rinsing the lapping blocks in trichloroethylene and scrubbing with a bristle brush.

When not in use, protect the lapping blocks against damage and dust by storing them in a close-fitting wooden container.

EFFECT OF PREIGNITION ON FUEL INJECTOR

Preignition is due to ignition of fuel or lubricating oil in the combustion chamber before the normal injection period. The piston compresses the burning mixture to excessive temperatures and pressures and may eventually cause burning of the injector spray tip, leading to failure of the injectors in other cylinders.

When preignition occurs, remove all of the injectors and check for burned spray tips or enlarged spray tip orifices.

Before replacing the injectors, check the engine for the cause of preignition to avoid recurrence of the problem. Check for oil pullover from the oil bath air cleaner, damaged blower housing gasket, defective blower oil seals, high crankcase pressure, plugged air box drains, ineffective oil control rings or dilution of the lubricating oil.

INJECTOR TIMING

If it is suspected that a fuel injector is "out of time", the injector rack-to- gear timing may be checked without disassembling the injector.

A hole located in the injector body, on the side opposite the identification tag, may be used to visually determine whether or not the injector rack and gear are correctly timed. When the rack is all the way in (full-fuel position), the flat side of the plunger will be visible in the hole, indicating that the injector is "in time". If the flat side of the plunger does not come into full view (Fig. 3) and appears in the "advanced" or "retarded" position, disassemble the injector and correct the rack-to-gear timing.

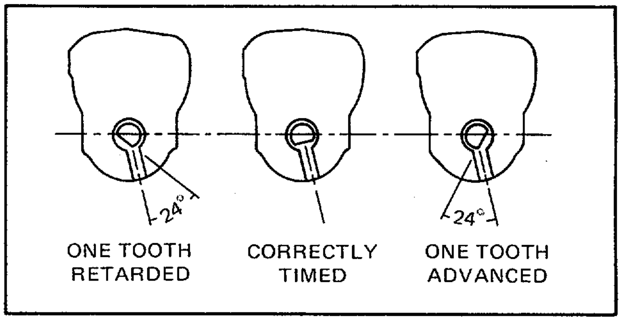


Figure 3. Injector Rack-to-Gear Timing

INJECTOR SPRAY TIPS

Due to a slight variation in the size of the small orifices in the end of each spray tip, the fuel output of an injector may be varied by replacing the spray tip.

Flow gage J 25600 may be used to select a spray tip that will increase or decrease fuel injector output for a particular injector after it has been rebuilt and tested on the calibrator.

INJECTOR PLUNGERS

The fuel output and the operating characteristics of an injector are, to a great extent, determined by the type of plunger used. Three types of plungers are illustrated in Fig. 4. The beginning of the injection period is controlled by the upper helix angle. The lower helix angle retards or advances the end of the injection period. Therefore, it is imperative that the correct plunger is installed whenever an injector is overhauled. If injectors with different type plungers (and spray tips) are mixed in an engine, erratic operation will result and may cause serious damage to the engine or to the equipment which it powers

Injector plungers cannot be reworked to change the output or operating characteristics. Grinding will destroy the hardened case and result in chipping at the helices and seizure or scoring of the plunger.

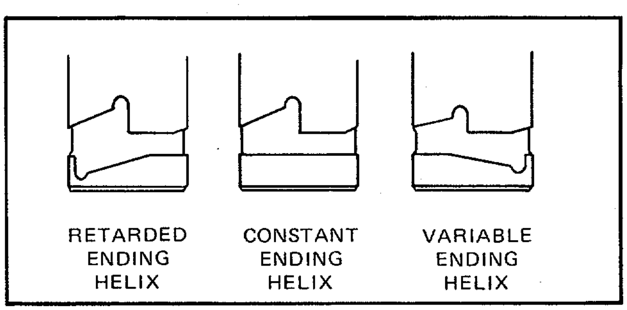


Figure 4. TYPES OF INJECTOR PLUNGERS

MASTER INJECTOR CALIBRATING KIT

Use Master Injector Calibrating Kit J 26298 to determine the accuracy of the injector calibrator.

With the test fluid temperature at 100°F ± 1° (38°C ± 1°) and each injector warm after several test cycles, run the three injectors contained in the kit. Several readings should be taken with each injector to check for accuracy and repeatability. If the output readings are within 2% of the values assigned to the calibrated masters, the calibrator can be considered accurate. Injector testing can be carried out now without any adjustment of figures. However, when testing new injectors for output, any difference between the calibrator and the masters should be used to compute new injector calibration.

If more than a 2% variation from the masters is noted, consult the calibrator manufacturer for possible causes.

The calibrated masters should only be used to qualify injector output calibration test equipment.

REFINISHING INJECTOR FOLLOWER FACE

When refinishing the face of an injector follower, it is extremely important that the distance between the follower face and the plunger slot is not less than 1.645 inches minimum as shown in Fig. 5. If this distance is less than specified, the height of the injector follower in relation to the injector body will be altered and proper injector timing cannot be realized.

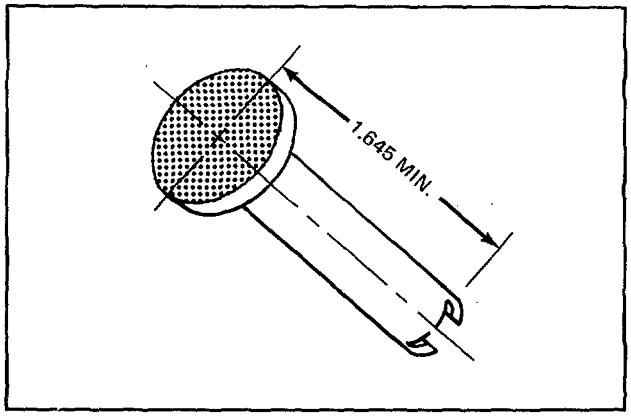


Figure 5. Injector Follower

FUEL LINES

Flexible fuel lines are used to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

Be sure a restricted fitting of the proper size is used to connect the fuel return line to the fuel return manifold. Do not use restricted fittings anywhere else in the fuel system.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine whether or not all connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check the filter cover bolts for tightness.

LOCATING AIR LEAKS IN FUEL LINES

Air drawn into the fuel system may result in uneven running of the engine, stalling when idling, or a loss of power. Poor engine operation is particularly noticeable at the lower engine speeds. An opening in the fuel suction lines may be too small for fuel to pass through but may allow appreciable quantities of air to enter. Check for loose or faulty connections. Also check for improper fuel line connections such as a fuel pump suction line connected to the short fuel return line in the fuel tank which would cause the pump to draw air.

Presence of an air leak may be detected by observing the fuel filter contents after the filter is bled and the engine is operated for 15 to 20 minutes at a fairly high speed. No leak is indicated if the filter shell is full when loosened from its cover. If the filter shell is only partly full, an air leak is indicated.

FUEL LEAK DETECTION

CAUTION

Always check the fuel system for leaks after injector or fuel pipe replacement and any time the fuel connections under the rocker cover are suspected of leaking. Failure to correct a serious fuel leak in this area can lead to dilution of the lube oil and bearing and/or cylinder kit damage.

Prime and Purge

Prime and/or purge the engine fuel system before starting the fuel leak check. Prime the system by blocking or disconnecting the line from the fuel pump, then apply fuel under pressure (60-80 psi or 413-552 kPa) to the inlet of the secondary filter. If the system is to be purged of air as well, allow the fuel to flow freely from the fuel return line until a solid stream without air bubbles is observed.

Check for Leaks

Use one of the following methods to check for leaks.

1. Method 1: Use when the engine has been operating 20-30 minutes.

After operating the engine, shut it off and remove the rocker covers. Inspect the lube oil puddles that normally form where the fuel connectors join the cylinder head and where the fuel pipes join the fuel pipe nuts.

If there is any leakage at these connections, the lube oil puddles will be smaller or thinner than the puddles on the connectors that are not leaking.

Disassemble, inspect and correct, or replace the suspect part (connector washer, connector, injector, or jumper line). Test and reinspect.

2. Method 2: Use when the engine is not operating, such as during or after repairs.

Remove the rocker covers. Pour lube oil over all fuel pipes and connectors which would normally be splashed with oil during engine operation. This will cause oil puddles to form at the joining surfaces as mentioned in Method 1.

Block off the fuel return line and disconnect the fuel pump supply line at the secondary filter. Install a pressure gage in the filter adaptor, then apply 60-80 psi (413-553 kPa) fuel to the outlet side of the secondary filter with the inlets plugged. Severe leaks will show up immediately. Minor leaks caused by nicks or burrs on sealing surfaces will take longer to appear. After maintaining 40-80 psi (276-552 kPa) for 20 to 30 minutes, a careful puddle inspection should reveal any suspect connectors. Inspect and repair or replace connectors as necessary. Test and reinspect (see note).

3. Method 3: Use while the engine is operating at 400-600 rpm.

Apply an outside fuel source capable of 60-80 psi (413-552 kPa) to the outlet side of the secondary filter. Pour lube oil over jumper lines and connectors so that oil puddles form where lines and connectors meet. Install a valve and a pressure gage in the fuel return line. With the engine idling, close the valve enough to raise the engine fuel pressure to 70 psi

(483 kPa). After 10 to 20 minutes inspect the oil puddles to see if any have become smaller or run off completely. The undiluted oil will hang the same as when the oil was poured on. Repair and retest.

NOTE

With the engine at rest as in Method 2, all injectors will leak to some extent when pressurized. The leakage occurs because there is no place else for the pressurized fuel to go. When the low- and high- pressure cavities in the injector are subjected to the high-test pressure, fuel is forced past the plunger into the rack and gear cavity. Result: Droplets of fuel form at the rack and drip off. Slightly worn plungers may leak more under these conditions. This leakage will not occur while the engine is running because of the dynamic and pressure conditions that exists. If injectors are suspected of leaking and contributing to dilution of the lube oil, they should not be tested by pressurizing the fuel system as in Method 2. Injectors should be removed from the engine and tested for pressure-holding capability (see *Troubleshooting*).

Points to Remember

Lube oil puddle inspection is the key to pressure testing the fuel system for internal leaks. This test can be performed any time the rocker covers are removed, after the fuel pipes and connectors have been splashed with oil and there is normal fuel pressure in the system. The weak or missing puddles show where the leaks are.

All leakage or spillage of fuel during leak detection testing further dilutes the lube oil, so the final step in maintenance of this type should include lube oil and lube oil filter changes.

TROUBLESHOOTING

FUEL PUMP

The fuel pump is so constructed as to be inherently trouble-free. By using clean, water-free fuel and maintaining the fuel filters in good condition, the fuel pump will provide long satisfactory service and require very little maintenance.

However, if the fuel pump fails to function satisfactorily, first check the fuel level in the fuel tank, then make sure the fuel-supply valve is open. Also check for external fuel leaks at the fuel line connections and filter gaskets. Make certain that all fuel lines are connected in their proper order.

Next, check for a broken pump drive shaft or drive coupling. Insert the end of a wire through the pump flange drain hole, then crank the engine momentarily and note whether the wire vibrates. Vibration will be felt if the pump shaft rotates.

All fuel pump failures result in no fuel or insufficient fuel being delivered to the fuel injectors and may be indicated by uneven running of the engine, excessive vibration, stalling at idling speeds or a loss of power.

The most common reason for failure of a fuel pump to function properly is a sticking relief valve. The relief valve, due to its close fit in the valve bore, may become stuck in a fully open or partially open position due to a small amount of grit or foreign material lodged between the valve and its bore or seat. This permits the fuel to circulate within the pump rather than being forced through the fuel system.

Therefore, if the fuel pump is not functioning properly, remove the relief-valve plug, spring and pin and check the movement of the valve within the valve bore. If the valve sticks, recondition it by using fine emery cloth to remove any scuff marks. Otherwise, replace the valve. Clean the valve bore and the valve components. Then lubricate the valve and check it for free movement throughout the entire length of its travel. Reinstall the valve.

After the relief valve has been checked, start the engine and check the fuel flow at some point between the restricted fitting in the fuel-return manifold at the cylinder head and the fuel tank.

CHECKING FUEL FLOW

1. Disconnect the fuel-return hose from the fitting at the fuel tank and hold the open end in a convenient receptacle (Fig. 1).

2. Start and run the engine at 1200 rpm and measure the fuel flow. Refer to *Engine Operating Conditions* for the specified quantity per minute.

3. Immerse the end of the fuel hose in the fuel in the container. Air bubbles rising to the surface of the fuel will indicate air being drawn into the fuel system on the suction side of the pump. If air is present, tighten all fuel line connections between the fuel tank and the fuel pump.

4. If the fuel flow is insufficient for satisfactory engine performance, then:

a. Replace the element in the fuel strainer. Then start the engine and run it at 1200 rpm to check the fuel flow. If the flow is still unsatisfactory, perform step b below:

b. Replace the element in the fuel filter. If the flow is still unsatisfactory, do as instructed in step c.

c. Substitute another fuel pump that is known to be in good condition and again check the fuel flow. When changing a fuel pump, clean all of the fuel lines with compressed air and be sure all fuel line connections are tight. Check the fuel lines for restrictions due to bends or other damage.

If the engine still does not perform satisfactorily, one or more fuel injectors may be at fault and may be checked as follows:

1. Run the engine at idle speed and cut out each injector in turn by holding the injector follower down with a screwdriver. If a cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine when that particular injector has been cut out.

2. Stop the engine and remove the fuel pipe between the fuel-return manifold and the injector.

3. Hold a finger over the injector fuel outlet and crank the engine with the starter. A gush of fuel while turning the engine indicates an ample fuel supply; otherwise, the injector filters are clogged and the injector must be removed for service.

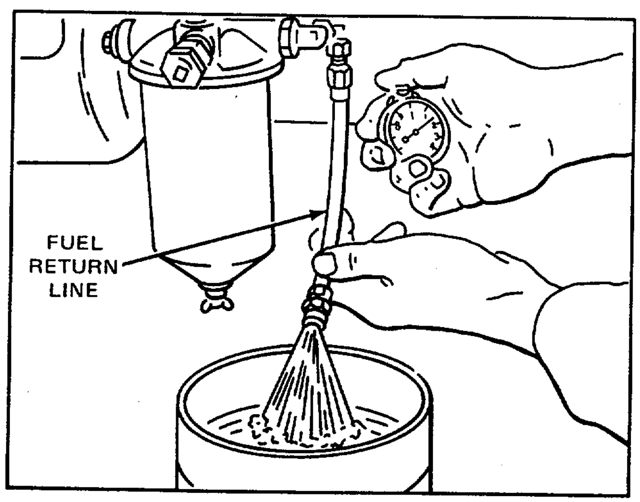
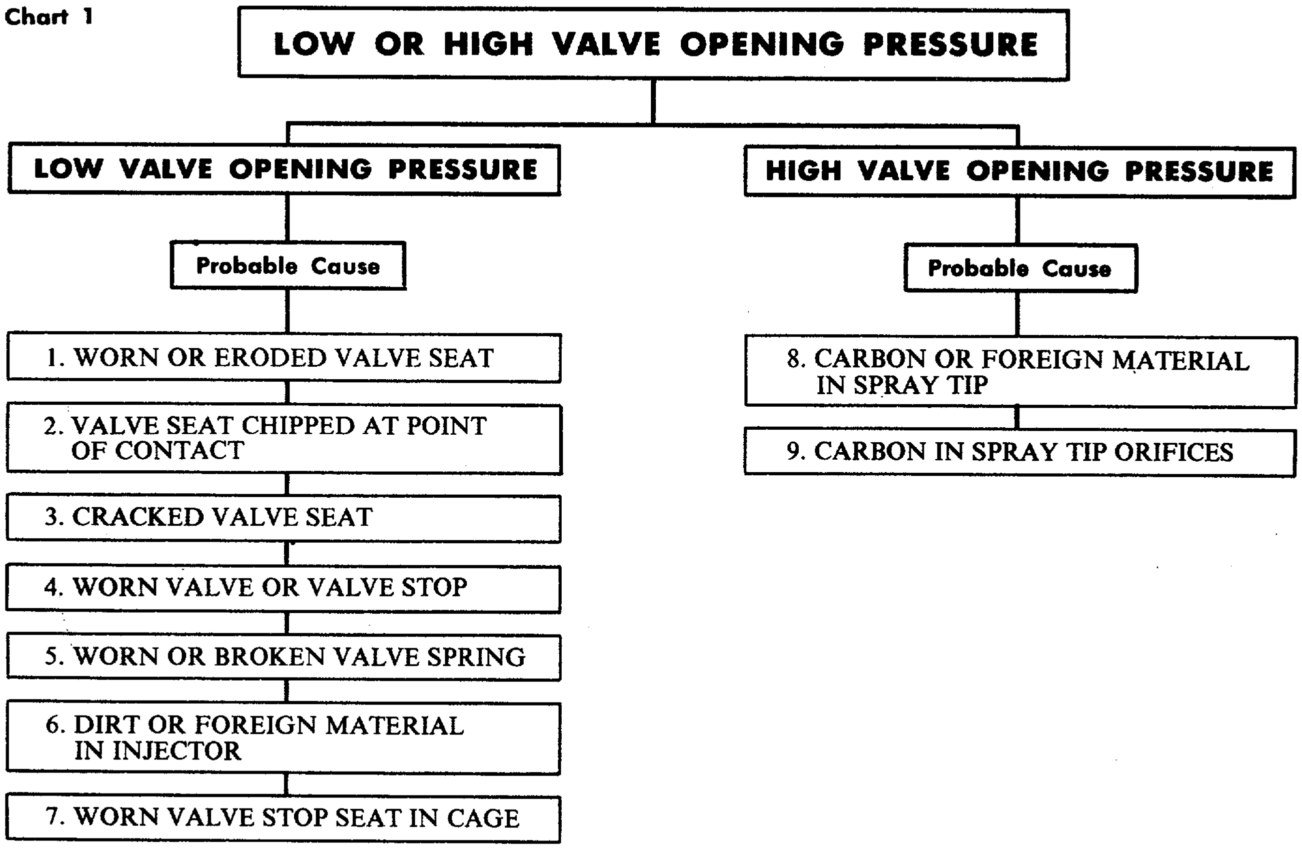


Figure 1. Measuring Fuel Flow

Chart 1



SUGGESTED REMEDY

1. A worn or eroded valve seat may be lapped, but not excessively as this would reduce thickness of the part causing a deviation from the valve stackup dimension.

2. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the ID of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve- opening pressure.

3. Replace the valve seat.

4. Replace the valve or valve stop.

5. Replace the spring. Check the valve cage and valve stop for wear; replace them if necessary.

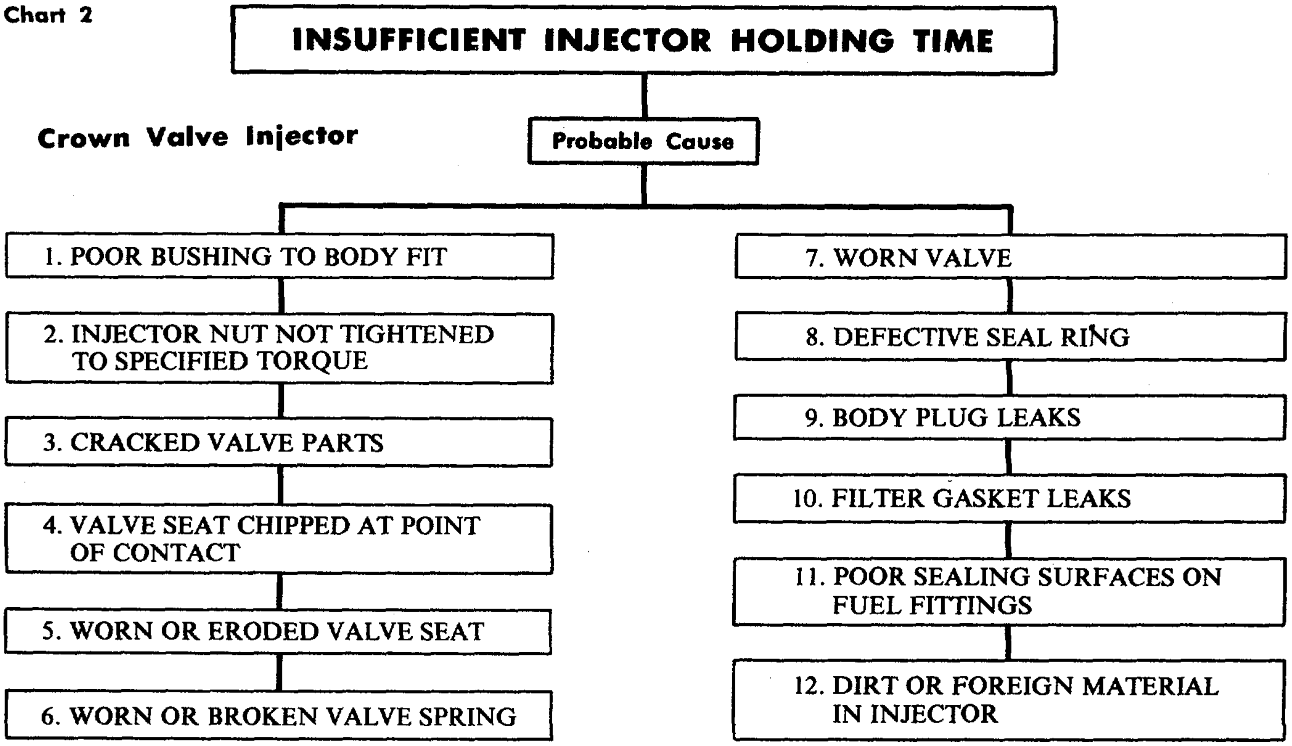
6. Disassemble and clean the injector.

7. Replace the valve cage.

8. Carbon in the tip should be removed with tip reamer J 1243 which is especially designed and ground for this purpose.

9. Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

Chart 2



SUGGESTED REMEDY

1. Lap the injector body.

2. Tighten the nut to 55 to 65 lb ft (75-88 Nm) torque. Do not exceed the specified torque.

3. Replace the valve parts.

4. If the valve seat is chipped at the point of contact with the valve, lap the surface of the seat and the ID of the hole. Mount tool J 7174 in a drill motor and place the valve seat on the pilot of the tool, using a small amount of lapping compound on the lapping surface. Start the drill motor and apply enough pressure to bring the seat to the point of lap. Check the point of lap contact after a few seconds. If the edge of the hole appears sharp and clear, no further lapping is required. Excessive lapping at this point will increase the size of the hole and lower the injector valve-opening pressure.

5. A worn or eroded valve seat may be lapped, but not excessively as this would reduce the thickness of the part causing a deviation from the valve stackup dimension.

6. Replace the spring. Check the valve cage and valve stop for wear; replace them if necessary.

7. Replace the valve.

8. Replace the seal ring.

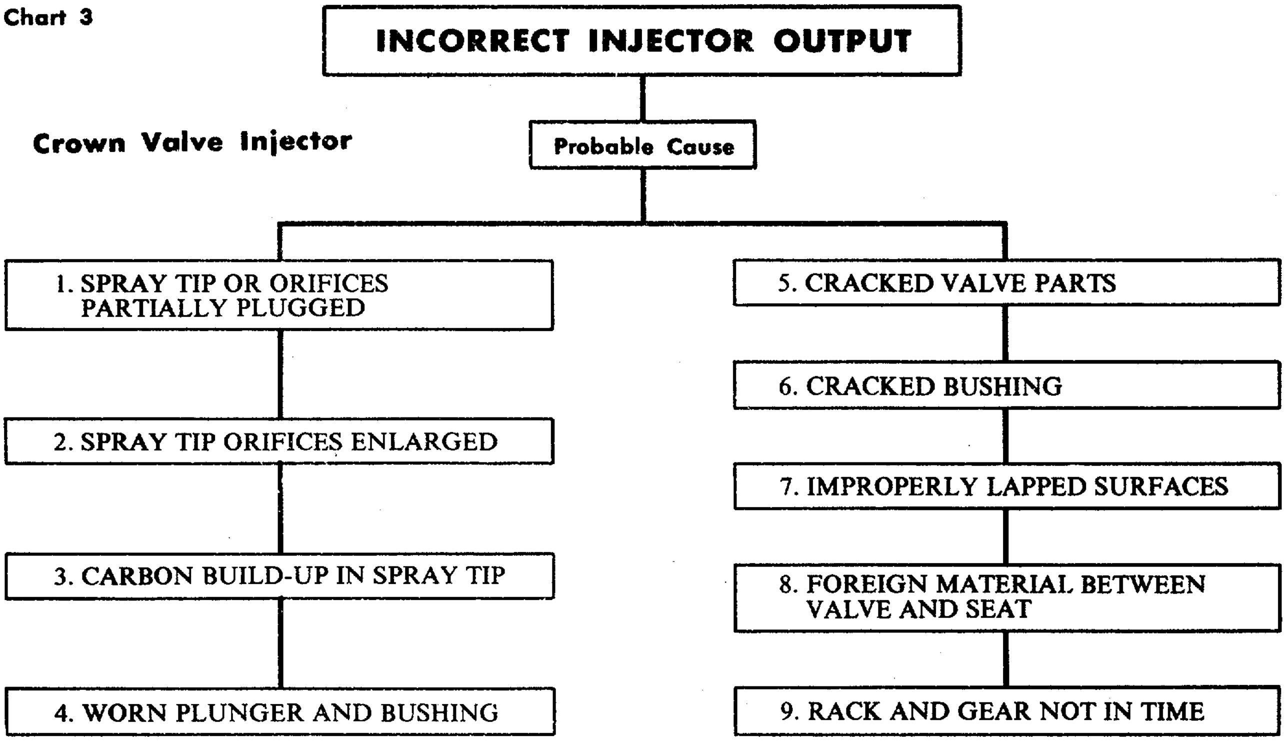
9. Install new body plugs.

10. Replace the filter gaskets and tighten the filter caps to 65 to 75 lb ft (88-102 Nm) torque.

11. Clean up the sealing surfaces or replace the filter caps, if necessary.

12. Disassemble the injector and clean all of the parts.

Chart 3



SUGGESTED REMEDY

1. Clean the orifices with tool 4298-1, using the proper size wire.

2. Replace the spray tip.

3. Clean the injector tip with tool 1243.

4. After the possibility of an incorrect or faulty tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

NOTE

The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the Fuel Output Check Chart, try changing the spray tip. However, use only a tip specified for the injector being tested.

5. Replace the cracked parts.

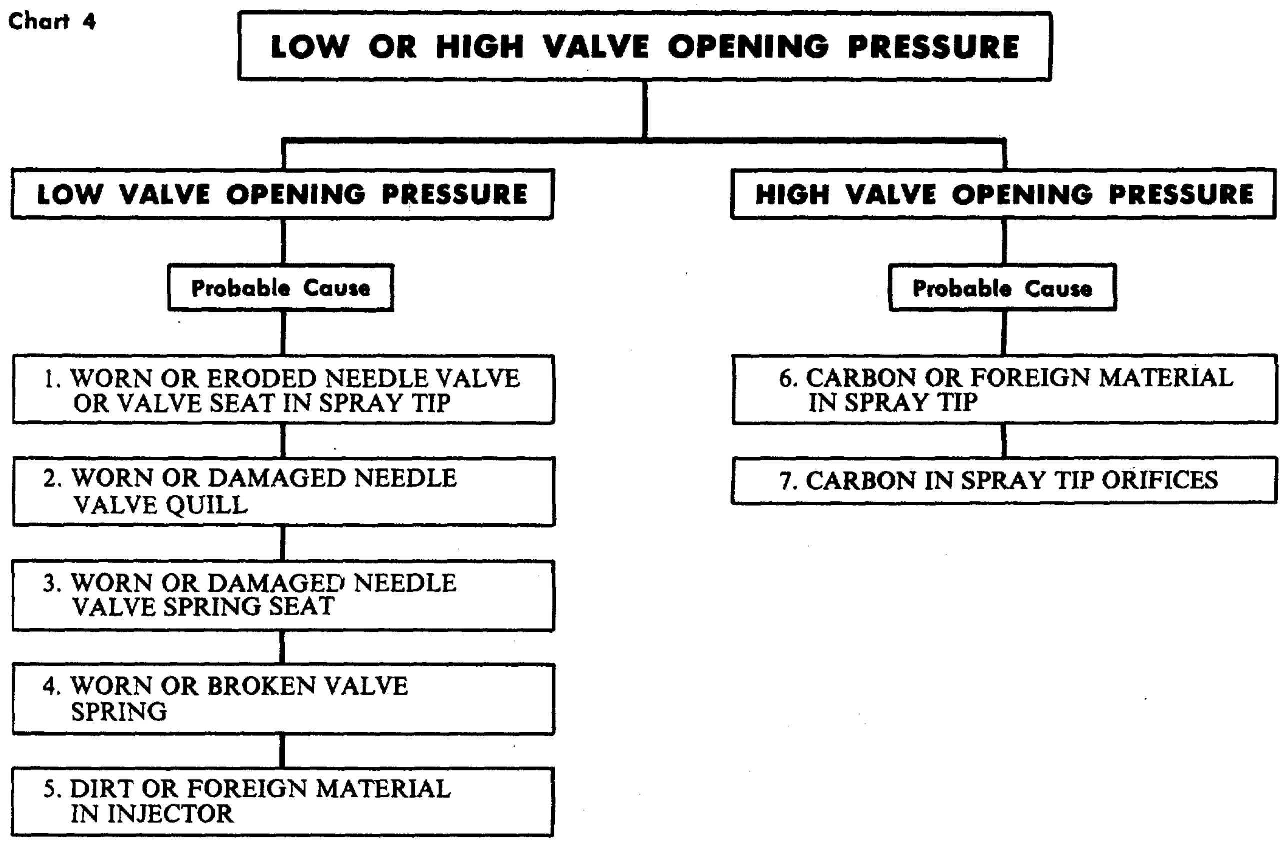
6. Replace the plunger and bushing assembly.

7. Lap the sealing surfaces.

8. Disassemble the injector and clean all of the parts.

9. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth of the rack.

TROUBLE SHOOTING CHARTS (Needle Valve Injectors)



SUGGESTED REMEDY

1. Replace the needle valve and spray tip assembly.

2. Replace the needle valve and spray tip assembly.

3. Replace the spring seat.

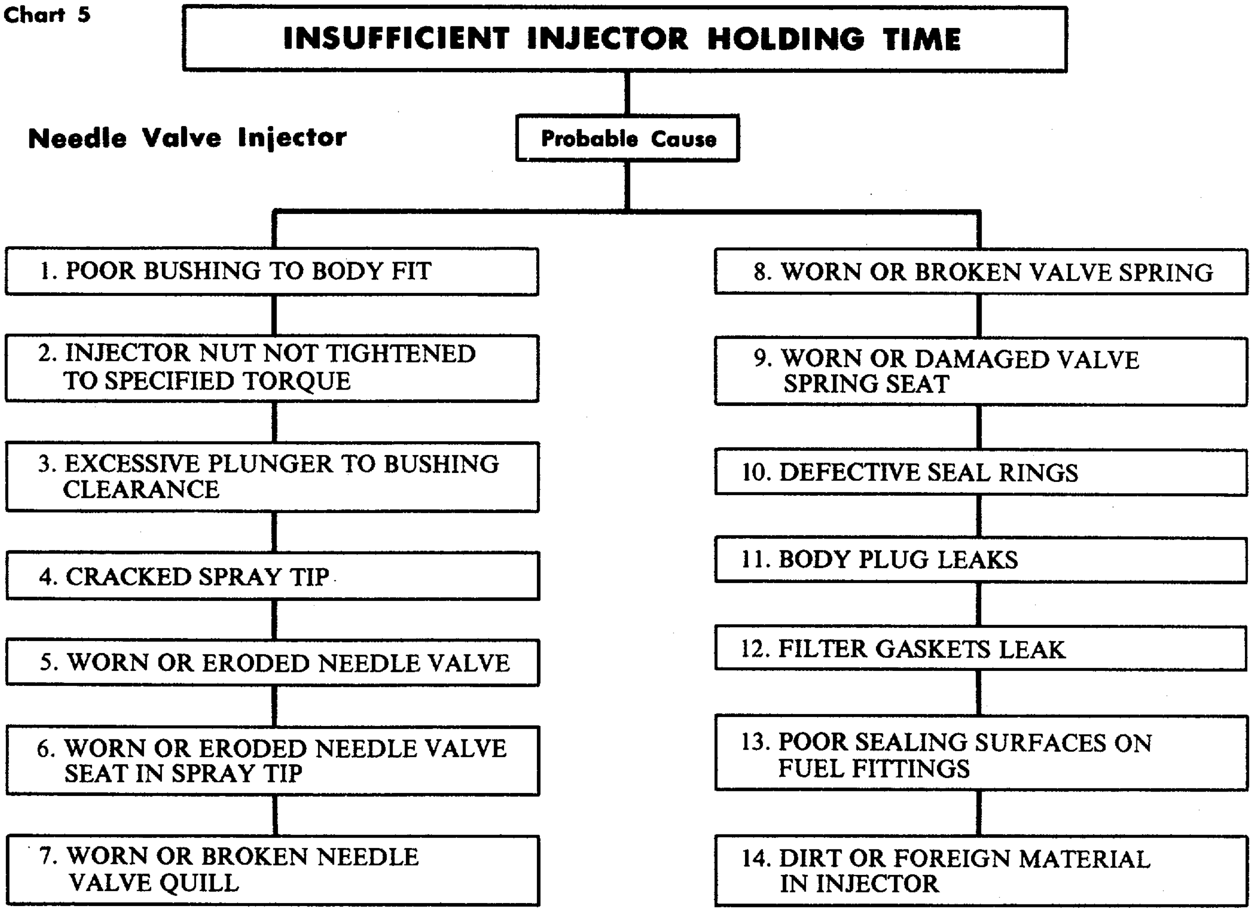
4. Replace the valve spring.

5. Disassemble the injector and clean all of the parts.

6. Remove the carbon in the spray tip with tip reamer J 9464-01 which is especially designed and ground for this purpose.

7. Check the size of the spray tip orifices. Then, using tool J 4298-1 with the proper size wire, clean the orifices.

Chart 5



1. Lap the injector body.

2. Tighten the injector nut to 75-85 lb ft (102-115 Nm) torque. Do not exceed the specified torque.

3. Replace the plunger and bushing.

4, 5, 6, and 7. Replace the needle valve and spray tip assembly.

8. Replace the valve spring.

9. Replace the valve spring seat.

10. Replace the seal rings.

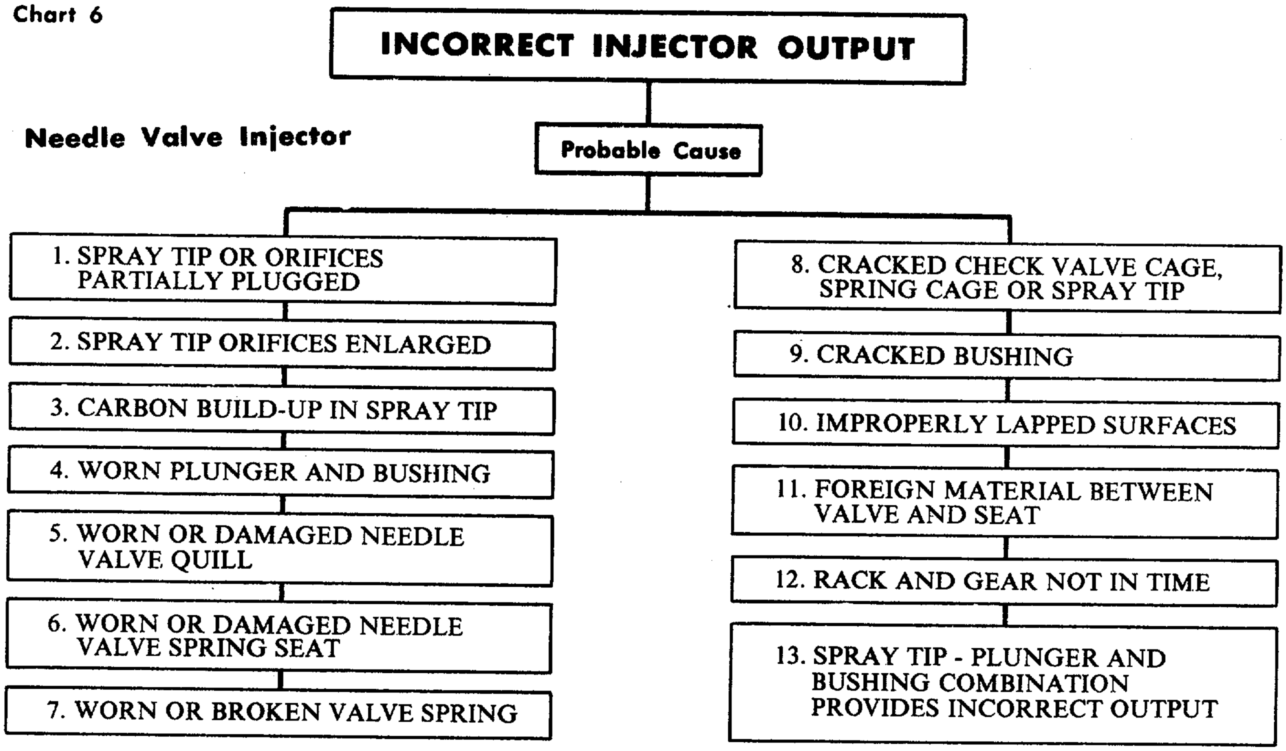
11. Install new body plugs.

12. Replace the filter cap gaskets and tighten the filter caps to 65-75 lb ft (88-102 Nm) torque.

13. Clean up the sealing surfaces or replace the filter caps, if necessary. Replace the filter if a cap is replaced.

14. Disassemble the injector and clean all of the parts.

Chart 6



SUGGESTED REMEDY

1. Clean the spray tip as outlined under *Clean Injector Parts.*

2. Replace the needle valve and spray tip assembly.

3. Clean the spray tip with tool J 1243.

4. After the possibility of an incorrect or faulty spray tip has been eliminated and the injector output still does not fall within its specific limits, replace the plunger and bushing with a new assembly.

NOTE

The fuel output of an injector varies with the use of different spray tips of the same size due to manufacturing tolerances in drilling the tips. If the fuel output does not fall within the specified limits of the Fuel Output Check Chart, try changing the spray tip. However, use only a tip specified for the injector being tested.

5. Replace the needle valve and spray tip assembly.

6. Replace the spring seat.

7. Replace the valve spring.

8. Replace the cracked parts.

9. Replace the plunger and bushing assembly.

10. Lap the sealing surfaces.

11. Disassemble the injector and clean all of the parts.

12. Assemble the gear with the drill spot mark on the tooth engaged between the two marked teeth on the rack.

13. Replace the spray tip and the plunger and bushing assembly to provide the correct output.

SPECIFICATIONS
STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb ft)	(Nm)	THREAD SIZE	280M OR BETTER TORQUE (lb ft)	(Nm)
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	810	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

BOLT IDENTIFICATION CHART

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM-260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM-275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	BM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Governor control housing to flywheel housing	5/16-18	10-12	14-16
Blower drive assembly to flywheel housing	3/8-16	20-25	27-34
Injector clamp bolt	3/8-16	20-25	27-34
Fuel line connector	3/8-24	20-28	27-38
Fuel pipe nut (V-engine)	3/8-24	12-15	16-20
Rocker arm bracket bolts	7/16-14	50-55	68-75
Governor drive gear retaining nut (in-line engine)	5/8-18	125-135	170-183
Injector filter cap	5/8-24	65-75	88-102
Injector nut (crown valve)	5/16-24	55-65	75-88
Injector nut (needle valve)	15/16-24	75-85	102-115

SERVICE TOOLS

TOOL NAME	TOOL NO.
INJECTOR	
Auxiliary injector tester ("N" injectors)	J 22640
Fuel pipe socket	J 8932-01
Fuel system primer	J 5956
Injector body reamer	J 21089
Injector body thread reconditioning set	J 22690
Injector bushing inspectalite	J 21471
Injector calibrator	J 22410
Injector nut seal ring installer	J 29197
Injector service set (includes *tools)	J 1241-07
Injector service set ("N" injectors - includes §tools)	J 23435-02
*Deburring tool	J 7174
§*Fuel hole brush	J 8152
§*Injector nut socket wrench	J 4983-01
§*Injector nut and seat carbon remover set	J 9418
§*Injector spray tip driver	J 1291-02
*Injector tip cleaner	J 1243
§*Pin vise	J 4298-1
§*Rack hole brush	J 8150
§*Spray tip carbon remover	J 9464-01
*Spray tip seat remover	J 4986-01
*Spray tip wire (0.005-inch)	J 21459-01
§*Spray tip wire (0.0055-inch)	J 21460-01
§*Spray tip wire (0.006-inch)	J 21461-01
§*Wire sharpening stone	J 8170
Injector test oil (Available in 5, 15, 30, and 55 gallons)	J 26400
Injector tester	J 9787
Injector tester	J 23010
Injector tester modification package (J 23010 only)	J 23010-194
Injector tip concentricity gage	J 5119
Injector vise and rack freeness tester	J 22396
Injector vise jaws (offset body)	J 8912
Injector vise jaws (standard body)	J 1261
Lapping Block set	J 22090
Methyl Ethyl Ketone cleaning fluid	J 8257-01
Polishing compound ("N" injectors)	J 23038
Polishing stick set ("N" injectors)	J 22964
Spray tip flow gage	J 25600
Spray tip gage ("N" injectors)	J 9462-01
Spring tester	J 22738-02
Wire brush (brass)	J 7944
INJECTOR TUBE	
Injector tube service tool set	J 22525
Injector tube service tool set (for power equipment)	J 22515

TOOL NAME	TOOL NO.

FUEL PUMP

Fuel pump primer	J 5956
Fuel pump tool set	J 1508-03
Fuel pump wrench	J 4242

MECHANICAL GOVERNOR

Adjustable spanner wrench	J 5345-5
Control link operating lever bearing remover/installer	J 8985
Governor cover bearing installer	J 21068
Governor cover bearing remover/installer	J 21967-01
Governor fork installer (8V engine)	J 21995
Governor weight spacer (6V engine)	J 8984
Spring retainer-nut wrench	J 5895
Variable speed spring housing bearing installer set	J 9196

AIR INTAKE SYSTEM

In the scavenging process employed in the Series 53 engines, a charge of air is forced into the cylinders by the blower and thoroughly sweeps out all of the burned gases through the exhaust valve ports. This air also helps to cool the internal engine parts, particularly the exhaust valves. At the beginning of the compression stroke, therefore, each cylinder is filled with fresh, clean air which provides for efficient combustion.

The air, entering the blower from the air cleaner, is picked up by the blower rotor lobes and carried to the discharge side of the blower as indicated by the arrows in Fig. 1. The continuous discharge of fresh air from the blower enters the air chamber of the cylinder block and sweeps through the intake ports of the cylinder liners.

The angle of the ports in the cylinder liners creates a uniform swirling motion to the intake air as it enters the cylinders. This motion persists throughout the compression stroke and facilitates scavenging and combustion.

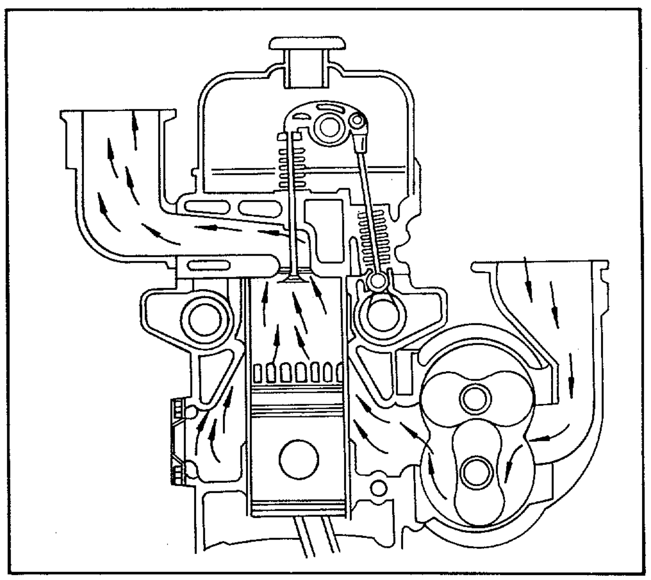


Figure 1. Air Flow Through Blower and Engine (In-Line Engine)

AIR SHUTDOWN HOUSING

The air shutdown housing on the in-line engine is mounted on the side of the blower. The housing serves as a mounting for the air cleaner or the ducting for an air cleaner mounted away from the engine. The air shutdown housing contains an air shutoff valve that shuts off the air supply and stops the engine whenever abnormal operating conditions require an emergency shut down.

Remove Air Shutdown Housing

1. Disconnect and remove the air ducts between the air cleaner and the air shutdown housing.

2. Disconnect the control wire from the air shutoff cam-pin handle.

3. Remove the bolts and washers that retain the housing to the blower and remove the housing from the blower. Remove the air shutdown housing gasket from the blower.

CAUTION

The bolts that retain the air inlet housing to the blower are of different lengths. Mark the location of each bolt to insure proper installation later.

CAUTION

Cover the blower opening to prevent dirt or foreign material from entering the blower.

Disassemble Air Shutdown Housing

Refer to Fig. 1 and disassemble the air shutdown housing as follows:

1. Remove the pin from the end of the shutdown shaft. Then remove the washer from the shaft and the seal ring from the housing.

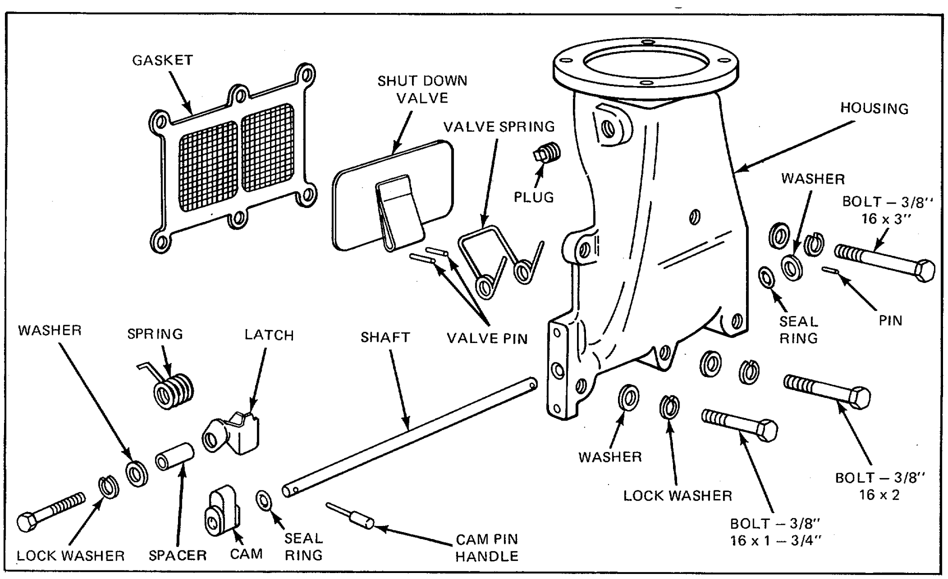


Figure 1. Typical In-Line Engine Air Shutdown Housing Details and Relative Location of Parts

2. Remove the two pins that secure the air shutoff valve to the shaft.
3. Remove the bolt, lockwasher, and plain washer which attach the latch to the housing. Then remove the latch, latch spring, and spacer.
4. Note the position of the air shutoff valve spring and the valve (Fig. 2). Then withdraw the shaft from the housing to release the valve and the spring. Remove the valve and spring and the seal ring from the housing.
5. Remove the cam-pin handle and withdraw the cam from the shaft.

Inspection

Clean all of the parts thoroughly, including the blower screen, with fuel oil and dry them with compressed air. Inspect the parts for wear or damage. The face of the air shutoff valve must be perfectly flat to assure a tight seal when it is in the shutdown position.

Assemble Air Shutdown Assembly

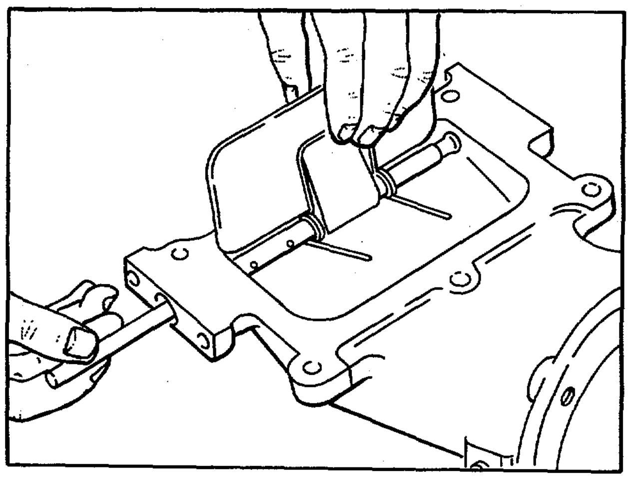


Figure 2. Installing Air Shutoff Valve Spring and Valve

The holes for the cam-pin handle and the retaining pins must be drilled, using a 1/8-inch-diameter drill, at the time a new service shaft or air shutoff valve(s) is assembled. The valve(s) must be in the same plane within 0.030 inch when in the stop position (flush with the housing face). Refer to Fig. 1 and 2 and proceed as follows:

1. Place the valve(s) and spring in position in the housing (Fig. 2) and slip the shaft in place. The shaft must extend 0.700 inch from the side of the housing where the shutdown latch is assembled.
2. Install a new seal ring at each end of the shaft. Be sure the seals are seated in the counterbores of the housing.
3. Install the cam and cam-pin handle on the shaft.
4. Install a washer and retaining pin at the other end of the shaft.
5. Assemble the spacer (bushing), spring, and latch to the shutdown housing with the 1/4 inch-20 bolt, lock-washer, and plain washer.
a. Align the notch on the bushing with the notch on the latch and lock the bushing in this position.
b. Install the pins in the valve(s) to retain it to the shaft with the cam release latch set and the valve(s) in the run position.
c Level the valve(s) in the shutdown position.
d. Adjust the bushing so the valve(s) contacts the housing when the cam release latch is set.

Install Air Shutdown Housing (In-Line Engines)

1. Place the blower screen and gasket assembly in position with the screen side of the assembly toward the blower.

2. Refer to Fig. 1 and 3 and secure the air shutdown housing to the blower with bolts, washers, and lockwashers as follows:

a. Install and finger-tighten the six attaching bolts shown in Fig. 3.

b. Tighten the two center bolts to 16-20 lb ft (22-27 Nm) torque.

c. Then tighten the four corner bolts to 16-20 lb ft (22-27 Nm) torque.

CAUTION

A power wrench should not be used to tighten the above bolts.

3. Reset the air shutdown to the run position.

4. Start and run the engine at idle speed and no load. Trip the air shutdown. If the engine does not stop, check it for air leakage between the valve and the gasket. If necessary, reposition the valve.

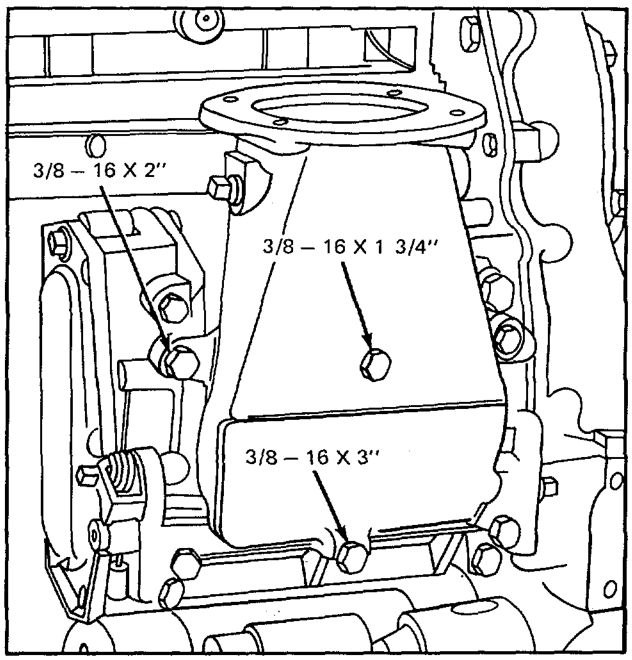


Figure 3. Location of Air Shutdown Housing Mounting Bolts (In-Line Engines)

BLOWER

The blower supplies the fresh air required for combustion and scavenging. Its operation is similar to that of a gear-type oil pump. Two hollow double-lobe rotors revolve in a housing bolted to the side of the in-line engines (Fig. 1). The revolving motion of the rotors provides a continuous and uniform displacement of air.

The blower rotors are pinned to the rotor shafts. The rotor shafts are steel and the blower end plates are aluminum, providing for a compatible bearing arrangement.

Gears located on the splined end of the rotor shafts space the rotor lobes with a close tolerance. Since the lobes of the two rotors do not touch at any time, no lubrication is required.

Lip-type oil seals are used in both the front and rear end plates on current engines. The seals prevent air leakage past the blower rotor shaft bearing surfaces and also keep the oil, used for lubricating the blower rotor gears, from entering the rotor compartment. Former blowers used a ring-type oil seal consisting of a fiber washer, O-ring, retainer, and seal spring in each end of the blower rotors.

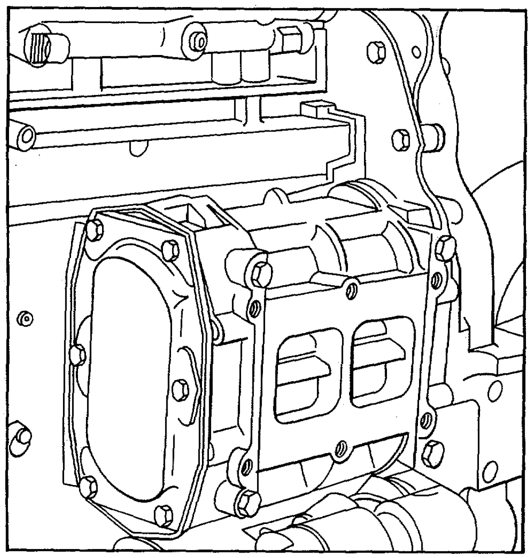


Figure 1. Blower Mounting

Inspect Blower (Attached to Engine)

The blower may be inspected without removing it from the engine. However, the air cleaner and the air inlet housing must be removed.

WARNING

When inspecting the blower with the engine running, keep your fingers and clothing away from the moving parts of the blower and run the engine at low speeds only.

Dirt or chips drawn through the blower will make deep scratches in the rotors and housing. Burrs around such abrasions may cause interference between the rotors or between the rotors and the blower housing.

Leaky oil seals are usually indicated by the presence of oil on the blower rotors or inside surfaces of the blower housing. Run the engine at low speed and direct a light into the rotor compartment and toward the end plates and the oil seals. A thin film of oil radiating away from a seal indicates an oil leak.
A worn blower drive resulting in a loose, rattling sound within the blower may be detected by running the engine at approximately 500 rpm.

Loose rotor shafts or worn rotor shaft bearing surfaces will result in contact between the rotor lobes, the rotors and the end plates, or the rotors and the housing.

Excessive backlash between the blower rotor gears usually results in the rotor lobes rubbing throughout their entire length.

Remove Blower

Before removing the blower from the engine, remove the air shutdown housing as outlined in *Air Shutdown Housing.*

1. Loosen the clamp retaining the cover-to-support seal.
2. Remove the four blower-to-block bolts and special washers and lift the blower away from the engine, being careful not to damage the serrations on the blower drive shaft.

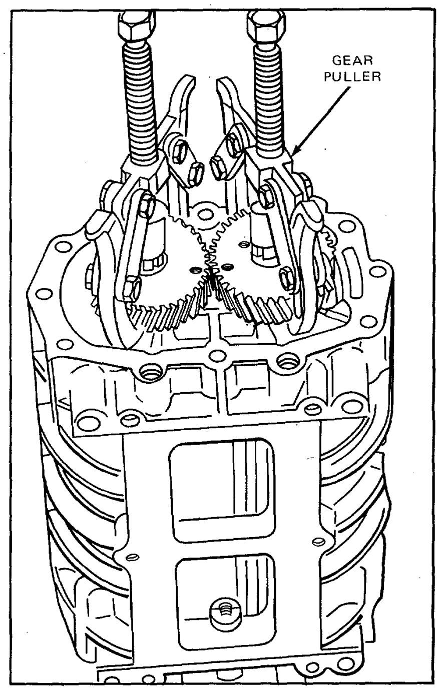


Figure 2. Removing Blower Rotor Gears

DISASSEMBLE BLOWER

1. Refer to Fig. 3 and remove the six bolts, special washers, and reinforcement plates which secure the front end plate cover and the front- end plate to the blower housing. Then remove the end plate cover and gasket from the end plate.
2. Remove the six bolts, special washers, and reinforcement plates which secure the rear end plate cover and the rear end plate to the blower housing. Then remove the end plate cover and gasket from the end plate.
3. Wedge a clean cloth between the rotors to prevent their turning and remove the four bolts that hold the blower drive cam retainer and blower drive spring support to the gear. Separate the retainer, support, and spacer from the gear.
4. Remove the retaining bolts and the washer and the blower drive cam pilot from the blower gears.
5. For identification, mark the upper gear on the blower.
6. Use two pullers J 24420 to remove the two gears simultaneously.
7. Remove the rotor shims and the gear spacers and place them with their respective gears to ensure correct reassembly.
8. At the other end of the blower, remove the three thrust plate bolts, the thrust plate and three spacers from the front end plate. Remove the bolts and thrust washers.
9. Tap the end plate off of the dowel pins and housing with a soft (plastic) hammer, being careful not to damage the mating surfaces of the end plate and the housing.

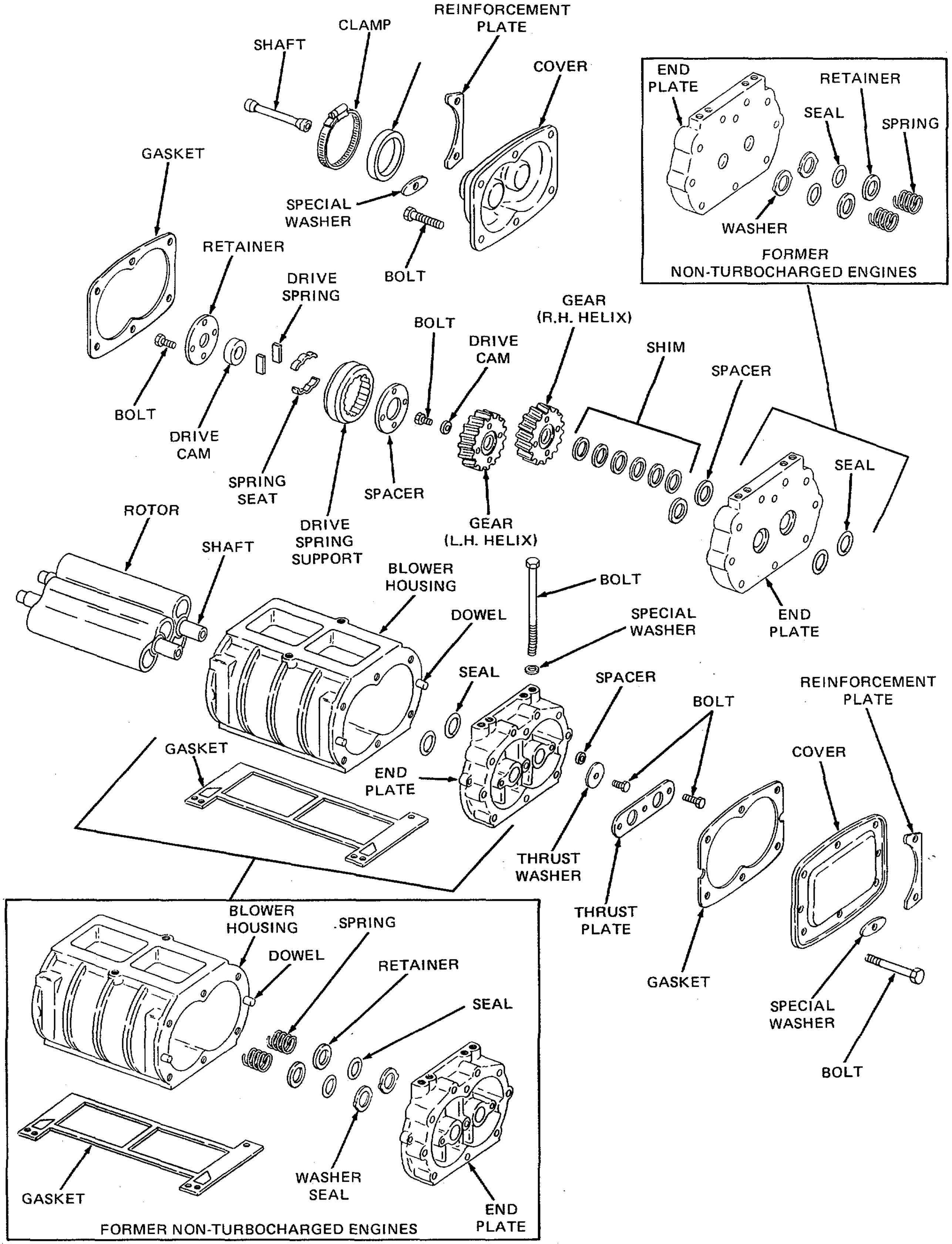


Figure 3. Typical Blower Details and Relative Location of Parts

10. Remove the rotors from the blower housing.
11. Remove the rear end plate as in Step 9.
12. Remove and discard the lip-type oil seals from the end plates on current blowers. Remove the seal washer, 0-ring, retainer and retainer spring from each rotor shaft on former blowers.
13. If required, disassemble the blower drive-spring support by driving the cam from the support with a brass drift, permitting the springs and spring seats to fall free.

Inspection

Clean and dry all of the parts thoroughly.

The finished inside face of each end plate must be smooth and flat. Slight scoring may be cleaned up with a fine grit emery cloth. If the surface is badly scored, replace the end plate.

Inspect the surfaces of the rotors and the blower housing. Remove burrs or scratches with an oil stone.

Examine the rotor shaft, gear, or drive coupling for burred or worn serrations.

Inspect the blower gears for excessive wear or damage.

Check the bearing and oil seal contact surfaces of the rotor shafts and end plates for scoring, wear, or nicks.

If an oversize oil seal is required, the sleeve on the rotor shaft can be installed as follows:

a. Place sleeve remover J 23679-2 over the rotor shaft and behind the oil seal sleeve.

BLOWER

b. Back out the center screw of one gear puller J 21672-4 and attach the puller to the sleeve remover with three 1/4-20 x 3-inch bolts and flat washers.
c. Turn the puller screw clock- wise and pull the sleeve off of the shaft.
d. Support the rotor, gear end up, on the bed of an arbor press.
e. Start a new sleeve straight on the shaft.
f. Place sleeve installer J 23679-1 on top of the sleeve and press the sleeve on the shaft until the step in the installer contacts the shoulder on the shaft.

NOTE

The step in the sleeve installer properly positions the sleeve on the shaft.

To replace the former O-ring oil seals by the current lip-type oil seals, rework the end plates by following the instructions given in Shop Notes.

Assemble Blower

Current front and rear blower end plates can now be identified either of two ways:

1. Knowing the machining differences, such as thrust washer drilling, governor hole drilling, counterbores drilled, etc (Fig. 4).
2. End plates are stamped with the last digit of its part number (Fig. 5). The end plate with a part number ending in 99 will have both numbers stamped in the plate.

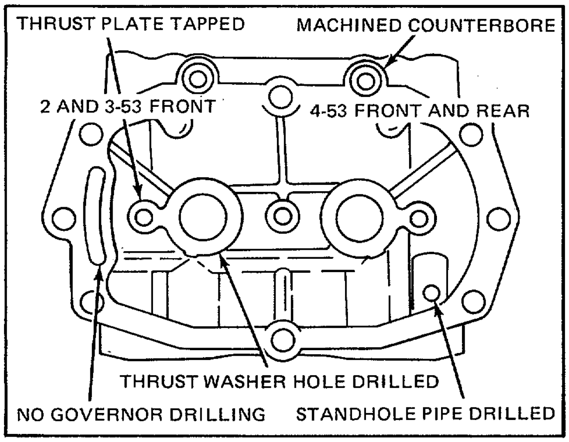


Figure 4. End Plate Machining Differences

Refer to Fig. 3 and assemble the blower as follows:

1. Install new lip-type oil seals in each end plate in current blowers as follows:

   a. Place the end plate on the bed of an arbor press.

   b. Lubricate the outer diameter of the seal and, using installer J 22576, press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate (Fig. 6).

NOTE

A step on the seal installer will position the oil seal below the finished face of the end plate within the 0.002 to 0.008 inch specified.

2. Install the ring-type oil seals on. the rotor shafts of former blowers as follows:

   a. Install a retainer spring on each shaft of each rotor. Then place an O-ring retainer (dished side up) on each spring.

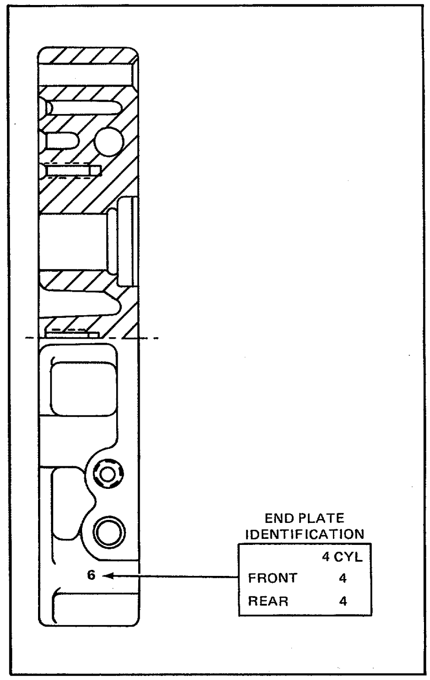


Figure 5. End Plate Identification

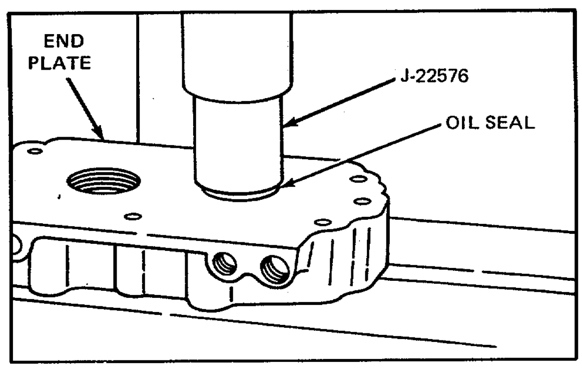


Figure 6. Installing Lip-Type Oil Seal in End Plate

b. Lubricate the O-rings with clean engine oil, then slide one ring on each shaft.

c. Lubricate and place a seal on each shaft. Note that the tangs on each seal are flush with one side of the seal; this side of the seal must face toward the rotor.

3. Place the front end plate on two woodblocks. Then install the rotors, gear end up, on the end plate (Fig. 7). On the former blowers, be sure that the ring-type oil seals are properly positioned on the rotors.

4. Install the blower housing over the rotors (Fig. 8).

CAUTION

To prevent inadequate lubrication or low oil pressure, care must be exercised in the assembly of the front and rear blower end plates to the blower housing.

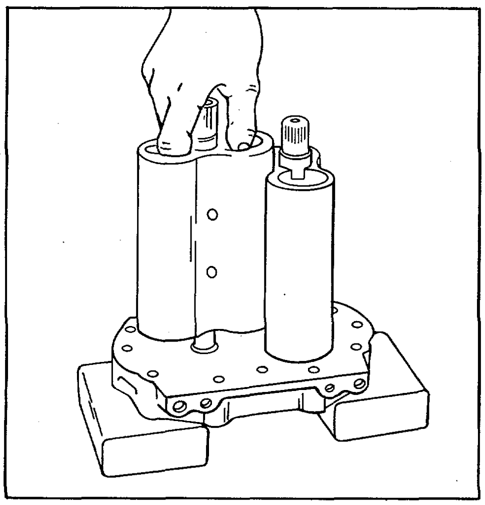


Figure 7. Installing Blower Rotors in Front-End Plate

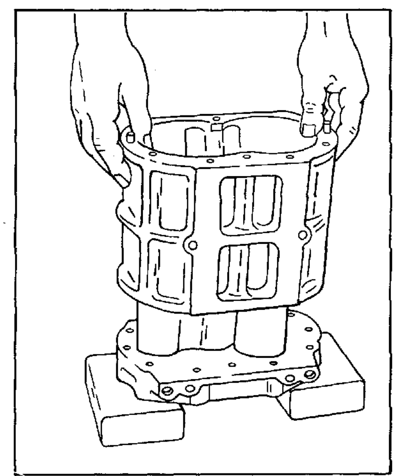


Figure 8. Installing Blower Rotors in Front-End Plate

5. Place the rear end plate over the rotor shafts (Fig. 9). On the former blowers, be sure that the ring-type oil seals are properly positioned on the rotors. Secure each end plate to the blower with four end plate cover bolts and plain washers.

6. Attach the two thrust washers to the front end of the blower with the washer retaining bolts. If 5/16-24 bolts are used, tighten them to 25-30 lb ft (34-41 Nm) torque; if 3/8-24 bolts are used, tighten them to 54-59 lb ft (73-80 Nm) torque.

7. Attach the three spacers and the thrust plate to the front end of the blower. Tighten the three bolts to 7-9 lb ft (10-12 Nm) torque. Then check the clearance between the thrust plate and the thrust washers. The specified clearance is 0.001 to 0.003 inch.

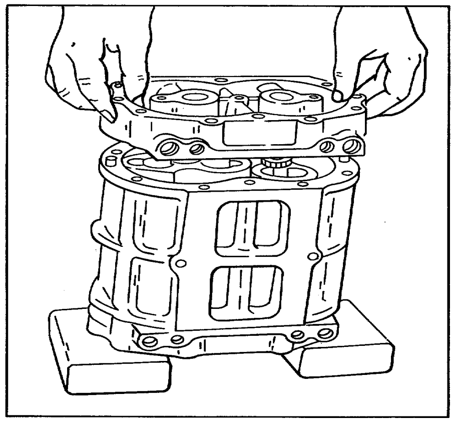


Figure 9. Installing Rear End Plate

NOTE

The current thrust plate is 0.260 inch thick. The former plate was 0.180 inch thick.

8. Position the rotors so that the missing serrations on the gear end of the rotor shafts are 90° apart. This is accomplished by placing the rotors in a "T" shape, with the missing serration in the upper rotor facing to the left and the missing serration in the lower rotor facing toward the bottom (Fig. 12). Install the shims and spacers in the counterbore in the rear face of the rotor gears. Then place the gears on the ends of the shafts with the missing serrations in alignment with the missing serrations on the shafts.

9. Tap the gears lightly with a soft hammer to seat them on the shafts.

Then rotate the gears until the punch marks on the face of the gears match. If the marks do not match, reposition the gears.

10. Wedge a clean cloth between the blower rotors. Use the gear-retaining bolts and plain washers to press the gears on the rotor shafts (Fig. 10). Turn the bolts uniformly until the gears are tight against the shoulders on the shafts.

11. Remove the gear retaining bolts and washers. Place the blower drive cam pilot in the counterbore of the upper gear and start the gear retaining bolt in the rotor shaft. Place the gear washer on the face of the lower gear and start the gear-retaining bolt in the rotor shaft. Tighten the bolts to 25-30 lb ft (34-41 Nm) torque.

12. Check the backlash between the blower gears, using a suitable dial indicator. The specified backlash is 0.0005 to 0.0025 inch with new gears or a maximum of 0.0035 inch with used gears.

13. Time blower rotors.

After the blower rotors and gears have been installed, the blower rotors must

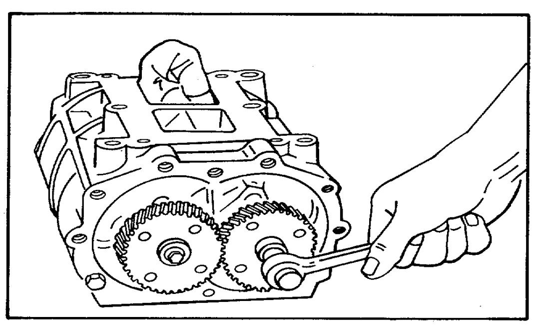


Figure 10. Installing Blower Rotor Gears

be timed. When properly positioned, the blower rotors run with a slight clearance between the rotor lobes and with a slight clearance between the lobes and the walls of the housing.

The clearances between the rotors may be established by moving one of the helical gears out or in on the shaft relative to the other gear by adding or removing shims between the gear hub and the rotor spacers.
It is preferable to measure the clearances with a feeler gage comprised of two or more feelers, since a combination is more flexible than a single feeler gage. A specially designed feeler gage set J 1698-02 for the blower clearance operation is available. Take measurements from both the inlet and outlet sides of the blower.

a. Measure the clearance between the rotor lobes and the housing as shown in Fig. 11. Take measurements across the entire length of each rotor lobe to be certain that a minimum clearance of 0.004 inch exists at the air outlet side of all blowers and a minimum clearance of 0.0075 inch exists at the air inlet side of the blower (Fig. 12).

b. Measure the clearance between the rotor lobes, across the length of the lobes, in a similar manner. By rotating the gears, position the lobes so that they are at their closest relative position (Fig. 12). The clearance between the lobes should be a minimum of 0.009 inch.

c. Measure the clearance between the end of the rotor and the blower end plate as shown in Fig. 13. Refer to the chart for the required minimum clearances.

NOTE

Push and hold the rotor toward the end plate at which the clearance is being measured.

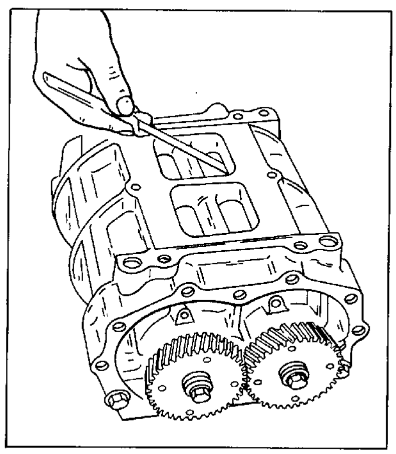


Figure 11. Measuring Rotor Lobe to Housing Clearance

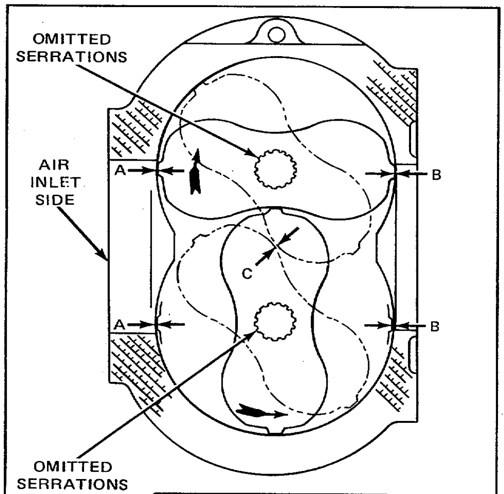
After timing the rotors, complete assembly of the blower.

14. Remove the bolts and washers used to temporarily secure the front end plate to the housing. Then install the front end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb ft (27-34 Nm) torque.

NOTE

The current front and rear end plate gaskets on the 4-53 engine blower are identical and may be used in either position. Formerly these gaskets were not interchangeable.

BLOWER ROTOR END CLEARANCES (Minimum)		
Engine	Front End Plate	Rear End Plate
4-53	0.006 inch	0.009 inch



	A	B	C
4-53	.0075"	.004"	.010"

Figure 12. Minimum Blower Rotor Clearance

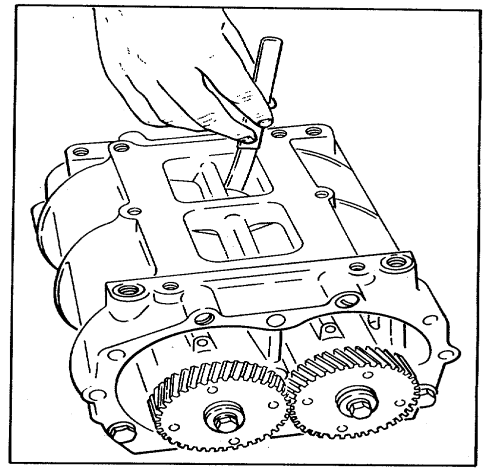


Figure 13. Measuring Rotor Lobe to End Plate Clearance

15. Assemble the blower drive spring support as follows:

a. Place the drive spring support on two blocks of wood (Fig. 14).

b. Position the drive spring seats in the support.

c. Apply grease to the springs to hold the leaves together, then slide the two spring packs (15 leaves per pack) in place.

d. Place the blower drive cam over the end of tool J 5209, insert the tool between the spring packs and press the cam in place.

16. Install the drive spring support coupling on the rotor gear at the rear end of the blower.

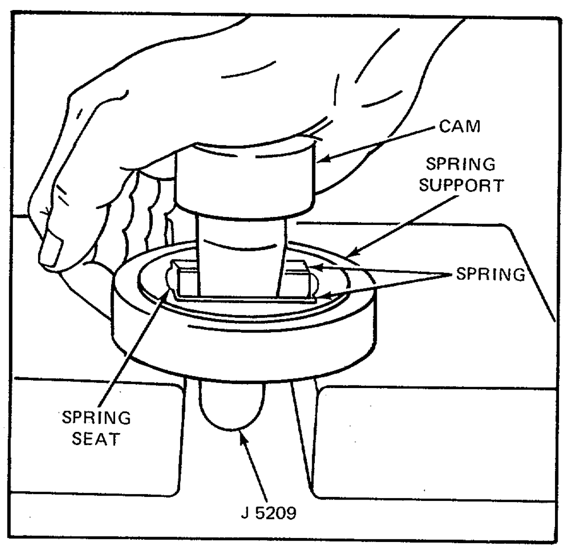


Figure 14. Inserting Cam in Blower Drive Support

IMPORTANT

Effective with engine serial number 4D-14120, the blower assembly for the 4-53 engine has been revised by the-use of a new longer drive gear pilot and the addition of a drive coupling spacer (Fig. 15). Tighten the 5/16-24 drive gear pilot bolt to 25-30 lb ft (34-41 Nm) torque. Prior to the above change; a shorter drive coupling was used and,-no spacer was required.,

NOTE

The coupling is placed on the upper rotor gear on the in-line engine blower.

17. Secure the cam retainer to the coupling with four 1/4-28 bolts and tighten them to 14-18 lb ft (19-24 Nm) torque.

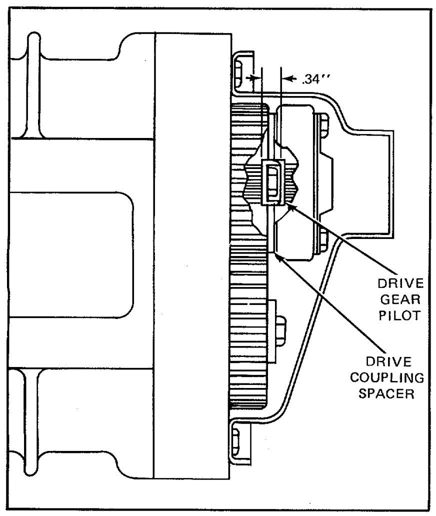


Figure 15. Current Pilot and Spacer Used on 4-53 Blower

18. Remove the bolts and washer used to temporarily secure the rear end plate to the 4-53 engine blower. Then install the rear end plate cover and gasket and secure the cover and end plate to the blower with six bolts and special washers and two reinforcement plates and tighten the bolts to 20-25 lb ft (27-34 Nm) torque.

Install Blower

Examine the inside of the blower for any foreign material. Also revolve the rotors by hand to be sure that they turn freely. Then install the blower on the engine as follows:

1. Affix a new blower-to-block gasket on the side of the cylinder block. Use Scotch Grip Rubber Adhesive No. 1300, or equivalent, only on the block side of the gasket.
2. Install the seal and clamp on the blower rear end plate cover.
3. Slide one end of the blower drive shaft into the drive cam.
4. Position the blower on the side of the cylinder block. Use care so that the blower gasket is not damaged or dislocated during installation of the blower.
5. Secure the blower to the cylinder block with bolts and washers. Tighten the bolts to 55-60 lb ft (75-81 Nm) torque,
6. Slide the seal and clamp back against the blower drive gear support and tighten the clamp to hold the seal in place.
7. Check the backlash between the blower drive gear and the camshaft gear. The backlash should be 0.003 to 0.007 inch.
8. Install the air shutdown housing as outlined in Air Shutdown Housing.

SHOP NOTES - TROUBLESHOOTING -

SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

On nonturbocharged engines built prior to serial number 4D-36457, when oil is detected on the -blower rotors or inside surface of the housing, the blower end plate can be reworked to accommodate a new lip-type oil seal or a steel insert.

NOTE

Slight phonographic grooves can actually improve sealing. Unless wear is considerable and oil leakage is evident, the end plate need not be reworked.

Rework Blower End Plate

Use tool kit J 9533 to rework the end plate.

NOTE

On some prior serviced blowers, the end plates may have been reworked to accommodate a steel insert. In such cases, proceed as follows but omit Step 10.

1. Adjust tool holder J 9533-2 and cutting tool J 9533-3 for the proper counterbore depth as follows:

   a. Insert rough cutting tool J 9533-3 in the tool holder as shown in Fig. 1.

   b. Position the holder and the cutting tool in the fixture J 9533-1.

   c. Loosen the upper knurled ring on the tool holder.

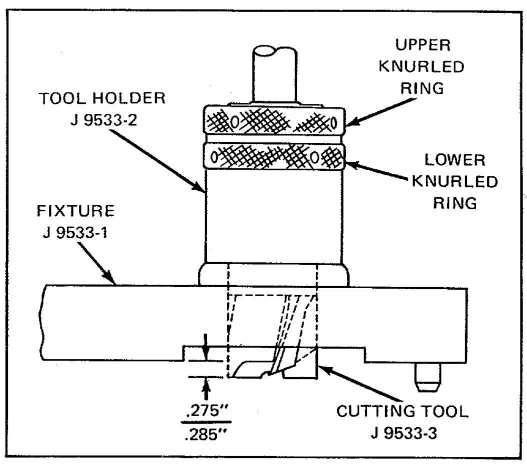


Figure 1. Adjustment of Tool Holder

   d. Rotate the lower knurled ring to raise or lower the cutting tool. Turn the lower knurled ring until there is a distance of 0.275-0.285 inch between the end of the cutting tool and the bottom of the fixture.

   e. Tighten the upper knurled ring.

2. Place fixture J 9533-1 on the blower end plate.

3. Clamp the fixture and the end plate loosely to the bed of a drill press.

4. Install tool holder J 9533-2 in the drill press and insert rough cutting tool J 9533-3 in the holder (Fig. 2).

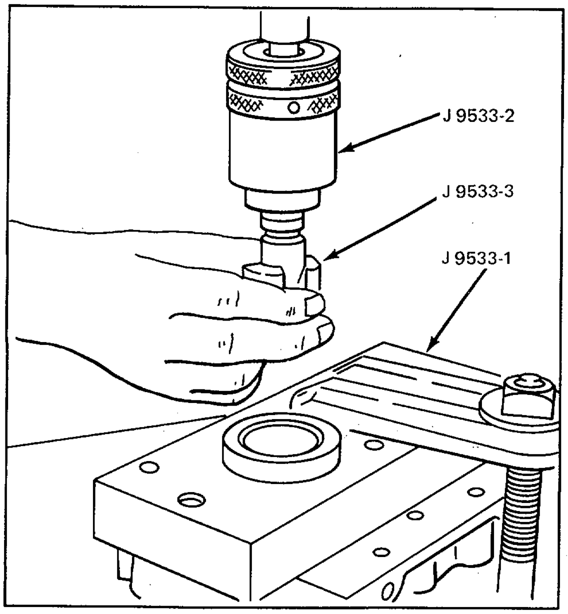


Figure 2. Install Cutting Tool in Holder

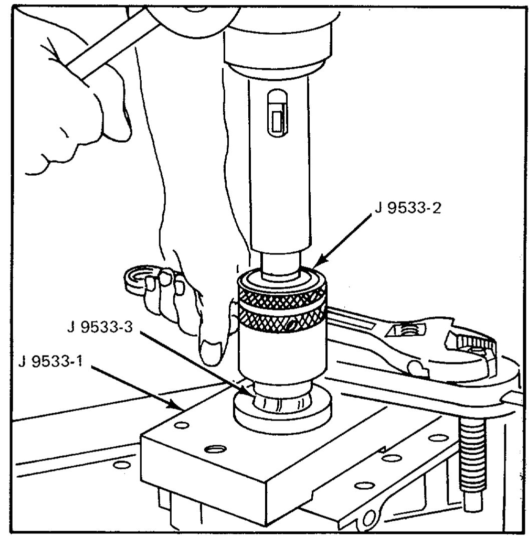


Figure 3. Positioning Cutting Tool in Fixture Guide

5. Position the cutting tool in the fixture guide as shown in Fig. 3. Operate the drill press at 75-100 rpm so as to center the cutting tool in the rotor shaft hole. Tighten the clamp.

6. Lubricate the cutting tool and the area of the end plate that is being reworked with a lubricant (mineral spirits or fuel oil).

7. Operate the drill press at 300- 350 rpm and slowly counterbore the hole until the collar of the tool holder is approximately 1/16 inch from the fixture guide. Then reduce the speed of the drill press to 75-100 rpm and continue counterboring until the collar contacts the top of the guide.

CAUTION

Raise the cutting tool periodically during the drilling operation and apply additional lubricant.

8. Stop the drill press and remove the rough cutting tool.

9. Insert finish cutting tool J 9533-4 in the holder. Lubricate the cutting tool and the end plate. Operate the drill press at 75-100 rpm and finish-cut the counterbore. Feed the cutting tool into the work slowly.

10. Remove the finish cutting tool and install an end mill to machine the additional 1.060 to 1.125-inches- diameter counterbore. The total depth of the combined counterbores is 0.440 inch (Fig. 4). The additional counter- bore provides proper oil drain back from the oil seal area.

11. Remove the fixture from the end plate. Wipe the cuttings from the end plate and fixture and dry the plate and fixture with compressed air. Remove any burrs from the edge of the oil hole.

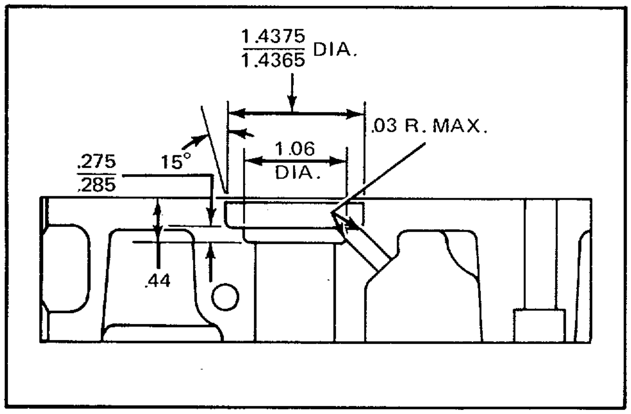


Figure 4. End Plate Oil Drain
Back Counterbore

12. Thoroughly clean the cutting tool and the end mill flutes and repeat the procedures for the adjacent rotor shaft hole.

13. Place the blower end plate on the bed of an arbor press. Use installer J 22576 to press the seal (lip facing down) into the counterbored hole until the shoulder on the installer contacts the end plate.

NOTE

A step under the shoulder of the installer will position the oil seal below the finished face of the end plate within the 0.002 to 0.008 inch specified.

Steel Inserts

To install steel inserts in the blower end plates, follow Steps 1 through 9 and 11 and 12. Press the inserts flush to 0.003 inch above the blower end plate surface.

AIR INTAKE SPECIFICATIONS - SERVICE TOOLS

SPECIFICATIONS

Specifications, clearances, and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled LIMITS in this chart lists the amount of wear or increase in clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the figures given as limits must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

TABLE OF SPECIFICATIONS, NEW CLEARANCES AND WEAR LIMITS

These limits also apply to oversize and undersize parts.

ENGINE PART (Standard Size, New)	MINIMUM (inch)	MAXIMUM (inch)	LIMITS (inch)
Blower			
Backlash--rotor gears (all)	0.0005	0.0025	0.0035
Backlash between blower drive gear and camshaft gear	0.0030	0.0070	
Clearances:			
Thrust plate and thrust washer	0.0010	0.0030	
Rotor to air outlet side of housing	0.0040		
Rotor to air inlet side of housing	0.0075		
Rotor to front end plate	0.0060		
Rotor to rear (gear) end plate	00090		

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb ft)	(Nm)	THREAD SIZE	280M OR BETTER TORQUE (lb ft)	(Nm)
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	8-10	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

BOLT IDENTIFICATION CHART

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM-260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Screws Only	GM-275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	BM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Blower drive coupling to rotor gear bolt (in-line and 6 V)	1/4-28	14-18	19-24
Blower drive gear pilot bolt	5/16-24	25-30	34-41
Blower thrust washer retaining bolt	5/16-24	25-30	34-41
Blower timing gear-to-rotor shaft bolts	5/16-24	25-30	34-41
Air inlet adaptor-to-blower bolts	3/8-16	16-20	22-27
Air inlet housing-to-adaptor or blower housing bolts	3/8-16	16-20	22-27
Blower drive gear cover bolt	3/8-16	20-24	27-33
Blower drive support-to-blower rear end plate bolts	3/8-16	20-24	27-33
Flywheel housing-to-blower drive support bolts	3/8-16	20-24	27-33
Front end plate cover bolts	3/8-16	20-25	27-34
Governor-to-blower front end plate bolts	3/8-16	20-24	27-33
Blower thrust washer retaining bolt	3/8-24	54-59	73-80
Blower end plate-to-block bolts	7/16-24	55-60	75-81

SERVICE TOOLS

TOOL NAME	TOOL NO.
BLOWER	
Blower clearance feeler gage set	J 1698-02
Blower drive cam installer	J 5209
Blower end plate counterbore set	J 9533
Blower gear puller (part of J 23679)	J 28483
Blower service set	J 23679
Blower service tool set	J 21672
Handle	J 7079-2
Universal puller	J 24420

LUBRICATION SYSTEM

The engine lubrication system, illustrated in Fig. 1, includes an oil in- take screen and tube assembly, an oil pump, an oil pressure regulator valve, a full-flow oil filter with a bypass valve, an oil cooler, and oil cooler bypass valve.

The rotor-type oil pump is bolted to the back of the engine lower front cover and is driven directly by the crankshaft.

Lubricating oil from the pump passes from the lower front engine cover through short gallery passages in the cylinder block. From the block, the oil flows to the full-flow filter, then through the oil cooler and back into the front engine cover and cylinder block oil galleries for distribution to the various engine bearings. The drain from the cylinder head and other engine parts leads back to the oil pan.

Clean engine oil is assured at all times by the use of a replaceable element-type full-flow filter. With this type filter, which is installed between the oil pump and the oil cooler, all of the oil is filtered before entering the engine. Should the filter become plugged, the oil will flow through a bypass valve, which opens at approximately 18-21 psi (124-145 kPa) directly to the oil cooler.

On current engines, the oil cooler by-pass valve is located on the right-hand side of the engine front cover and the oil pressure regulator valve is located on the left-hand side as viewed from the rear of the engine (Fig. 1). On former engines, both valves were located on the right-hand side of the cover (Fig. 1).

If the cooler becomes plugged, the oil flow will be to a bypass valve in the lower engine front cover and then to the cylinder block oil galleries. The bypass valve opens at approximately 52 psi (359 kPa) in the current in-line engines. In the former in-line engines, the bypass valve opens at approximately 30 psi (207 kPa).

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve located in the lower front engine cover. The regulator valve, located in the pump outlet passage, opens at 51 psi (352 kPa) on in-line engines or 52 psi (359 kPa) on 6V engines and returns excess oil directly to the crankcase.

Lubricating Oil Distribution

Oil from the oil cooler on the in-line engine is directed to the lower engine front cover and then to a longitudinal main oil gallery in the cylinder block. As shown in Fig. 1, this gallery distributes the oil, under pressure, to the main bearings and to a horizontal transverse passage at one end of the block and to vertical passages at each corner of the block which provide lubrication for the balance shaft and camshaft bearings. The camshaft bearings incorporate small slots through which lubricating oil is directed to the cam follower rollers.

Oil for lubricating the connecting-rod bearings, piston pins, and for cooling the piston head is provided through the drilled crankshaft from the adjacent forward main bearings. The gear train is lubricated by the overflow of oil from the camshaft pocket through a communicating passage into the flywheel housing. Some oil spills into the flywheel housing from the bearings of the camshafts and balance shaft.

Drilled oil passages on the camshaft side of the cylinder head (Fig. 1) are supplied with oil from the bores located at each end of the cylinder

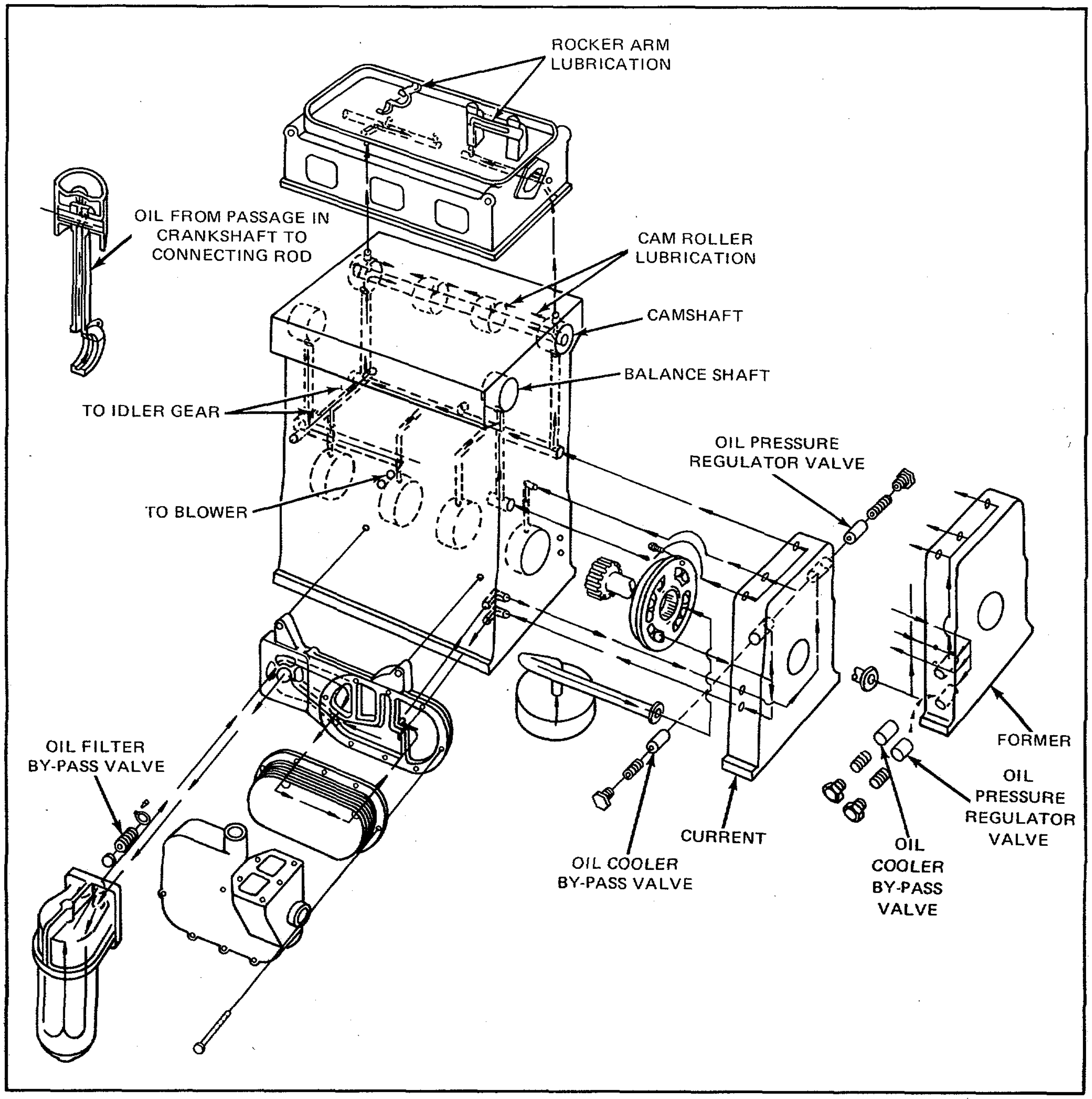


Figure 1. Schematic Diagram of Typical In-Line Engine Lubrication System

block. Oil from these drilled passages enters the drilled rocker shaft brackets at the lower ends of the drilled bolts and lubricates the rocker-arm bearings and push-rod clevis bearings.

Excess oil from the rocker arms lubricates the lower ends of the push rods and cam followers, then drains to cam pockets in the top of the cylinder block, from which the cams are lubricated. When these pockets are filled, the oil overflows through holes at each end of the cylinder block and then through the flywheel housing and front cover to the crankcase.

The blower bearings are pressure lubricated by oil from drilled passages in the cylinder block which connect matching passages in the blower end plates which, in turn, lead to the bearings. On current engines, lubricating oil is supplied directly to the front and rear right bank camshaft end bearings and supplies oil to the blower bearings. On former engines, the blower bearings received lubrication indirectly via the right rear camshaft end bearing only. Excess oil returns to the crankcase via drain holes in the blower end plates which lead to corresponding drain holes in the cylinder block.

One tapped oil pressure take-off hole is provided in the lower engine front cover on some in-line engines. In addition, tapped oil holes in the cylinder block, on the side opposite the blower, are also provided with three holes in the four-cylinder block.

Lubricating System Maintenance

Use the proper viscosity grade and type of heavy-duty oil as outlined in the Lubricating Oil Specifications. Change the oil and replace the oil filter elements at the periods recommended by the oil supplier (based on his analysis of the drained engine oil) to ensure trouble-free lubrication and longer engine life.

The oil level should never be allowed to drop below the low mark on the dip-stick. Overfilling the crankcase may contribute to abnormal oil consumption, high oil temperatures, and also result in oil leaking past the crankshaft rear oil seal.

To obtain the true oil level, the engine should be stopped and sufficient time (approximately twenty minutes) allowed for the oil to drain back from the various parts of the engine. If more oil is required, add only enough to bring it to the proper level on the dipstick.

Cleaning Lubrication System

Thorough flushing of the lubrication system is required at times. Should the engine lubrication system become contaminated by ethylene glycol anti-freeze solution or other soluble material, refer to *Cooling System* for the recommended cleaning procedure.

OIL PRESSURE TAKE-OFF LOCATIONS

The cylinder block illustrations in Fig. 2 show the main oil gallery pressure locations that are available for supplying oil under pressure to oil gages, Jacobs engine brake, or other accessories.

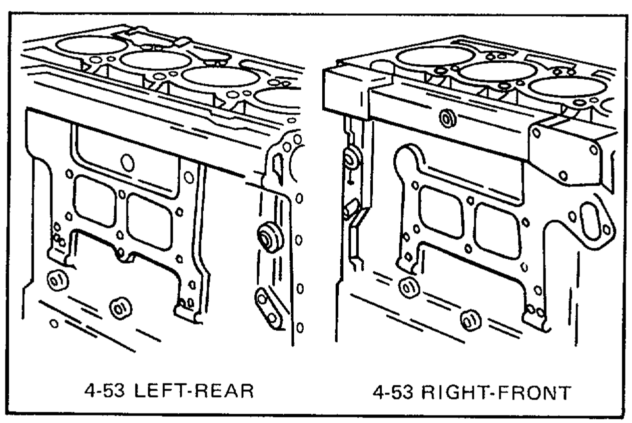


Figure 2. Oil Pressure Take-Off Locations

LUBRICATING OIL PUMP

The lubricating oil pump, assembled to the inside of the lower engine front cover as illustrated in Fig. 1, is of the rotor-type in which the inner rotor is driven by a gear pressed on the front end of the crankshaft. The outer rotor is driven by the inner rotor. The bore in the pump body, in which the outer rotor revolves, is eccentric to the crankshaft and inner rotor. Since the outer rotor has nine cavities and the inner rotor has eight lobes, the outer rotor revolves at eight-ninths crankshaft speed. Only one lobe of the inner rotor is in full engagement with the cavity of the outer rotor at any given time, so the former can revolve inside the latter without interference.

Operation

As the rotors revolve, a vacuum is formed on the inlet side of the pump and oil is drawn from the crankcase, through the oil pump inlet pipe and a passage in the front cover, to the inlet port, and then into the rotor compartment of the pump. Oil drawn into the cavities between the inner and outer rotors on the inlet side of the pump is then forced out under pressure through the discharge port into a passage in the front cover, which leads to the lubricating oil filter and cooler, and is then distributed throughout the engine.

If a check of the lubrication system indicates improper operation of the oil pump, remove and disassemble it as outlined below.

Remove Oil Pump

1. Drain the oil from the engine.

2. Remove the crankshaft pulley, fan pulley, support bracket, and any other accessories attached to the front cover.

3. Remove the oil pan.

4. Refer to Fig. 2 and remove the four bolts which attach the oil pump inlet pipe and screen assembly to the main bearing cap and engine front cover or oil pump inlet elbow. Slide the flange and the seal ring on the inlet pipe and remove the pipe and screen as

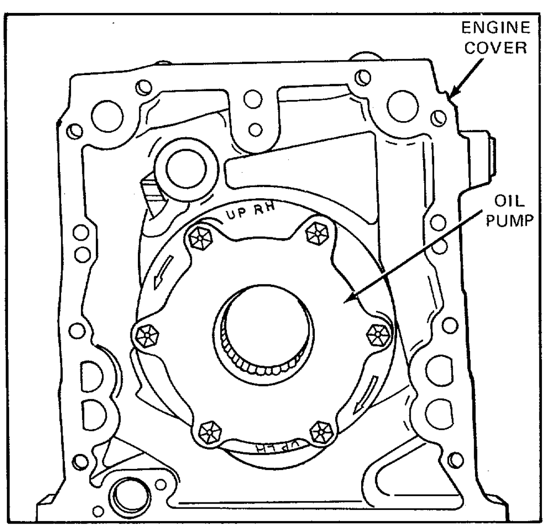


Figure 1. Typical Right-Hand Rotation Oil Pump Mounting

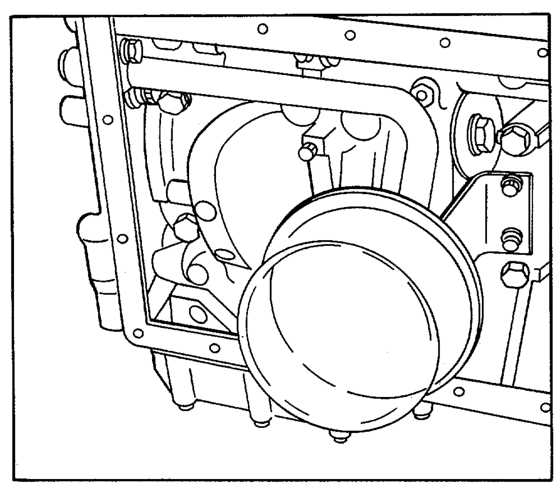


Figure 2. Typical Oil Pump Inlet Pipe and Screen Mounting

an assembly. Remove the oil pump inlet elbow (if used) and gasket from the engine front cover.

5. Remove the lower engine front cover.
6. Remove the six bolts and lock- washers (if used) which attach the pump assembly to the engine front cover (Fig. 1) and withdraw the pump assembly from the cover.

Disassemble Oil Pump

If the oil pump is to be disassembled for inspection or reconditioning, proceed as follows:
1. Refer to Fig. 5 or 6 and remove the two drive screws holding the pump cover plate to the pump body. Withdraw the cover plate from the pump body.
2. Remove the inner and outer rotors from the pump housing.

Inspection

Wash all of the parts in clean fuel oil and dry them with compressed air. The greatest amount of wear in the oil pump-is imposed on the lobes of the inner and outer rotors. This wear may be kept to a minimum by using clean oil. If dirt and sludge are allowed to accumulate in the lubricating system, excessive rotor wear may occur in a comparatively short period of time. Inspect the lobes and faces of the pump rotors for scratches or burrs and the surfaces of the pump body and cover plate for scoring. Scratches or score marks may be removed with an emery stone. Measure the clearance between the inner and outer rotors at each lobe (Fig. 3).

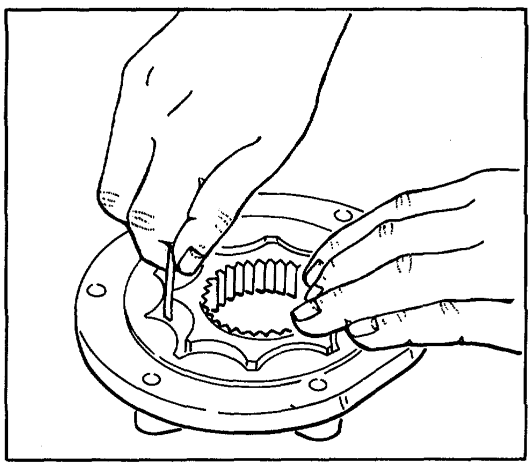


Figure 3. Measuring Rotor Clearance

The clearance should not be less than 0.004 inch or more than 0.011 inch. Measure the clearance from the face of the pump body to the side of the inner and outer rotor with a micrometer depth gage (Fig. 4). The clearance should not be less than 0.001 inch or more than 0.0035 inch. Inspect the splines of the inner rotor and the oil pump drive gear. If the splines are excessively worn, replace the parts. The rotors are serviced as matched sets, therefore, if one rotor needs replacing, replace both rotors. Remove the oil inlet screen from the oil inlet pipe and clean both the screen and the pipe with fuel oil and dry them-with compressed air. Replace the inlet pipe flange seal ring with a new seal ring.

Assemble Oil Pump

After the oil pump parts have been cleaned and inspected, refer to Fig. 5 or 6 and assemble the pump as follows:

1. Lubricate the oil pump outer rotor with engine oil and place it in the pump body.

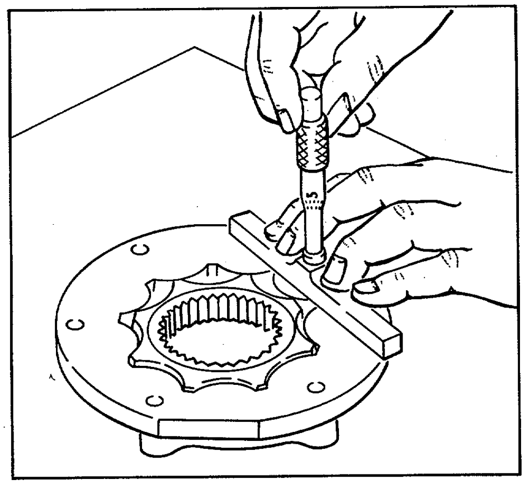


Figure 4. Measuring Clearance from Face of Pump Body to Side of Rotor

2. Lubricate the oil pump inner rotor with engine oil and place it inside of the outer rotor.
3. Place the cover plate on the pump body and align the drive-screw and boltholes with the holes in the pump body. Since the holes are offset, the cover plate can be installed in only one position.
4. Install two new drive screws to hold the assembly together.

Remove Pump Drive Gear From Crankshaft

With the lower engine front cover and the lubricating oil pump removed from the engine, the oil pump drive gear may, if necessary, be removed from the end of the crankshaft as follows:

1. Thread the crankshaft pulley-retaining bolt in the end of the crankshaft (Fig. 7).
2. Attach the jaws of a suitable gear puller behind the gear and locate the end of the puller screw in the center of the pulley-retaining bolt.
3. Turn the puller screw clockwise to remove the gear from the crankshaft.

Install Pump Drive Gear on Crankshaft

1. Lubricate the inside diameter of a new oil pump drive gear with engine oil. Then start the gear straight on the crankshaft with the chamfered edge of the gear toward the butt end of the crankshaft. Reinstallation of a used gear is not recommended.
2. Position the drive-gear installer J 8968-01 over the end of the crank- shaft and against the drive gear and force the gear in place as shown in Fig. 8. When the end of the bore in the tool contacts the end of the crankshaft, the drive gear is correctly positioned (2.680 inches from the front end of the crankshaft to the forward face of the gear).
3. It is important that the press fit of the drive gear to the crankshaft be checked to be sure that the gear does not slip on the crankshaft. It is recommended that the -press fit (slip torque) be checked with tool J 23126. On in-line engines, the drive gear should not slip on the crankshaft at 100 lb ft (136 Nm) torque.

CAUTION

Do not exceed this torque. If the gear slips on the shaft, it is suggested that another oil pump drive gear be installed.

Install Oil Pump

1. The markings on the pump body indicate the installation as pertaining to left- or right-hand crankshaft rotation. Be sure that the letters UP R.H. (right-hand rotation engine) on the pump body are at the top (Fig. 1).

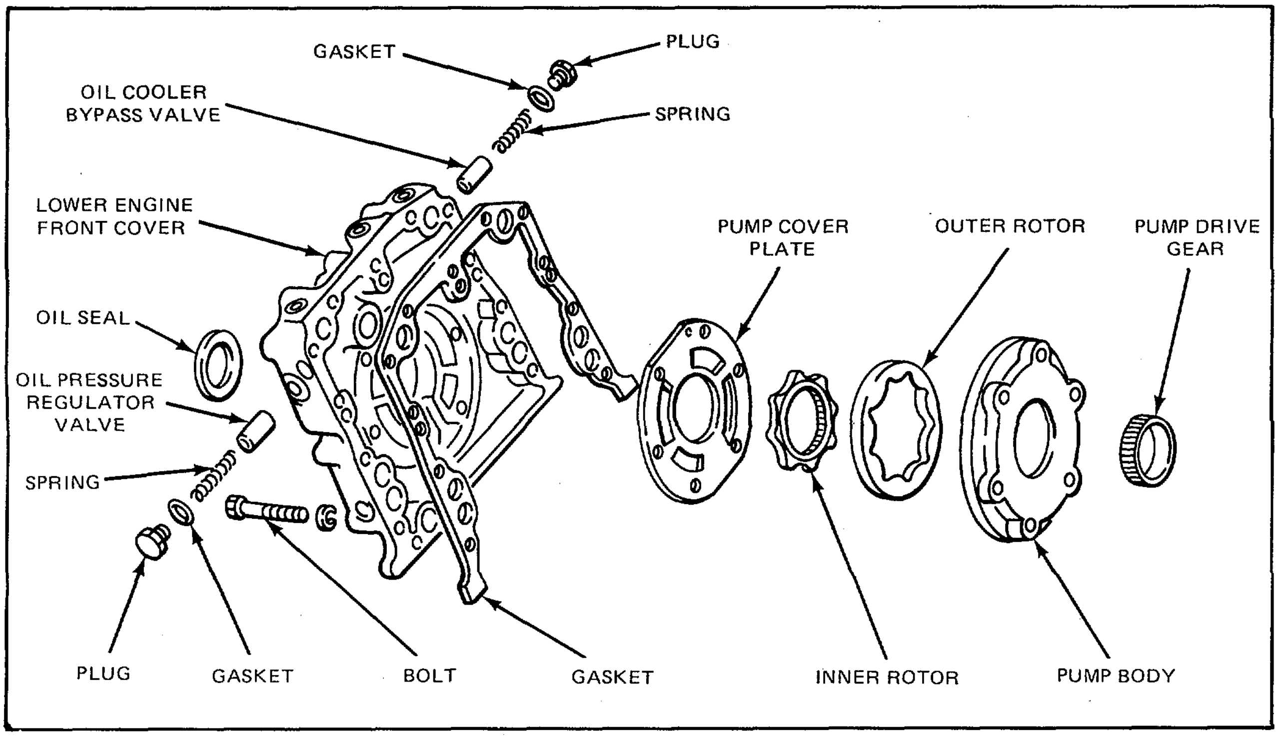


Figure 5. Oil Pump Details and Relative Location of Parts (Current)

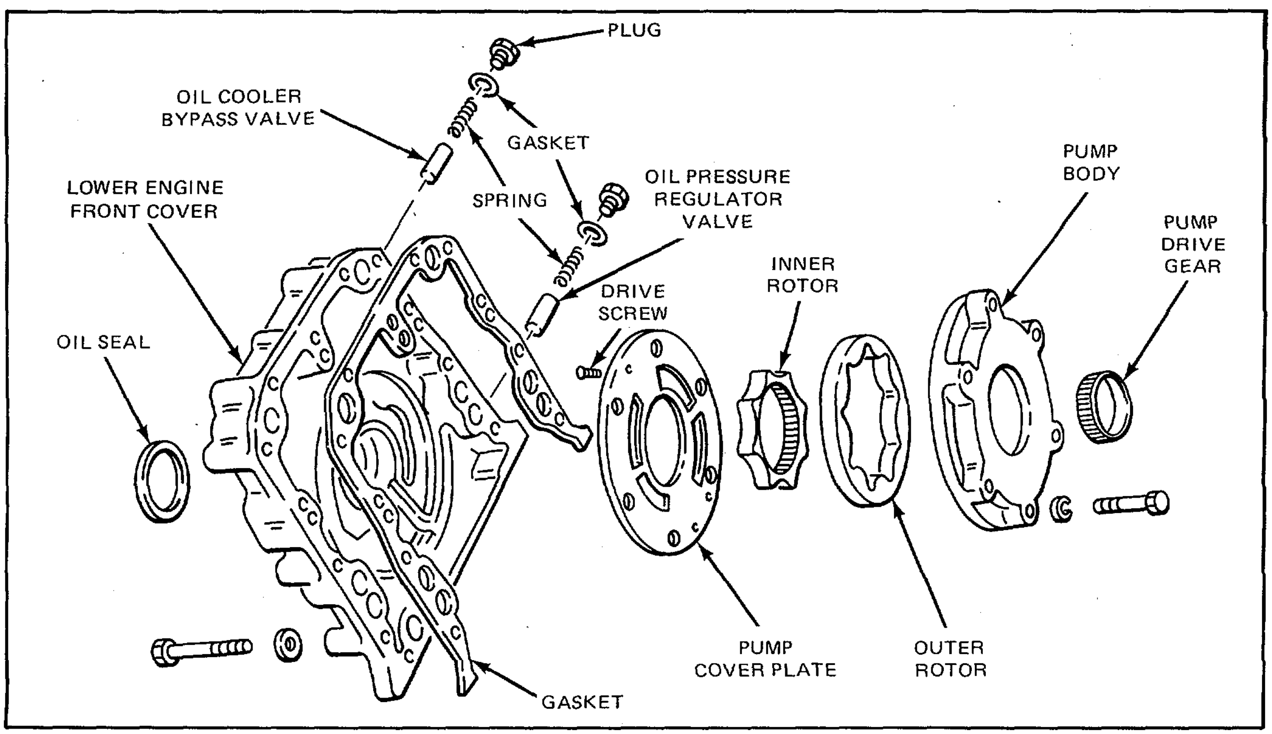


Figure 6. Oil Pump Details and Relative Location of Parts (Former)

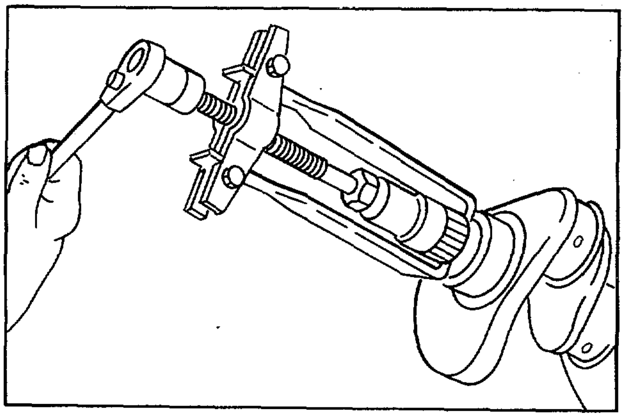


Figure 7. Removing Oil Pump Drive Gear

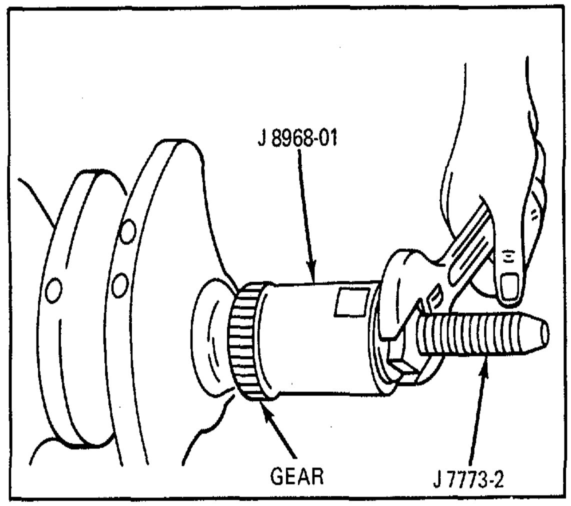


Figure 8. Installing Oil Pump Drive Gear

2. Insert the six bolts with lock- washers (if used) through the pump body and thread them into the engine front cover. Tighten the bolts to 13-17 lb ft (18-23 Nm) torque.
3. Install the lower engine front cover and pump assembly on the engine as outlined in *Engine Front Cover (Lower).*
4. Attach the oil inlet screen to the oil inlet pipe support with two bolts and lockwashers (Fig. 9).

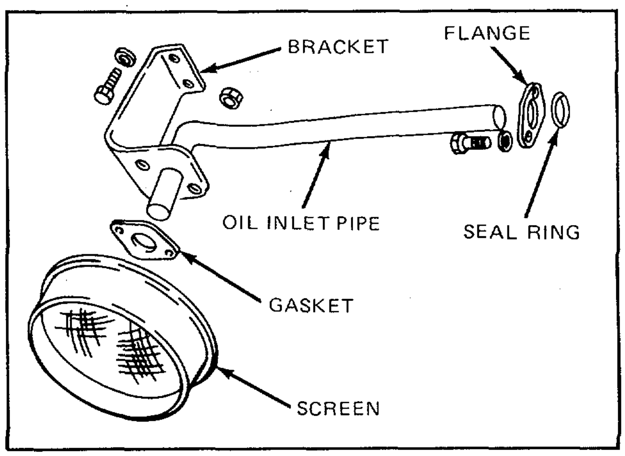


Figure 9. Oil Pump Inlet Pipe and Screen Details and Relative Location of Parts (In-Line Engine)

5. Place the oil pump inlet pipe and screen assembly in position and fasten the support to the main bearing cap with two bolts and lockwashers.
6. Slide the inlet pipe flange and seal ring against the engine front cover and secure them with the two bolts and lockwashers.

CAUTION

On in-line engines, the oil pump inlet tube and water by-pass tube seals are the same size but of different material. Be sure that the correct seal is used. A new oil pump inlet tube seal may be identified by its white stripe.

7. Install the oil pan and refill the crankcase to the proper level.
8. Install the crankshaft pulley, fan pulley, support bracket, and any other accessories that were attached to the front cover.

LUBRICATING OIL PRESSURE REGULATOR

Stabilized lubricating oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by an oil pressure regulator valve installed in the engine lower front cover as shown in Fig. 1. The oil pressure regulator consists of a hollow piston-type valve, a spring, gasket, and plug. The valve is located in an oil gallery within the lower front cover and is held tight against a counterbored valve seat by the valve spring and plug. When the oil pressure exceeds a given value (Table 1), the valve is forced from its seat and the lubricating oil is bypassed into the engine oil pan. Under normal conditions, the pressure-regulator valve should require very little attention. If sludge accumulates in the lubrication system, the valve may not work freely, thereby remaining open or failing to open at the normal operating pressure.

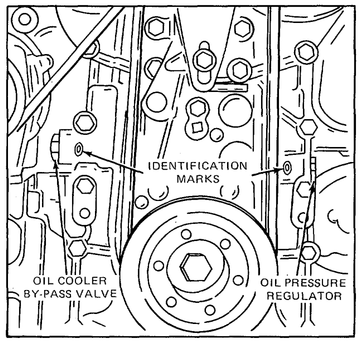


Figure 1. Location of Current Oil Pressure Regulator Valve

TABLE 1

Engine	Front Cover	Valve Opening Pressure	
		psi	kPa
In-line	Former	78	538
	Current	51	352

Whenever the lubricating oil pump is removed for inspection, the regulator valve and spring should also be removed, thoroughly cleaned in fuel oil and inspected.

Remove Oil Pressure Regulator

1. Remove the plug and washer from the engine lower front cover.

2. Withdraw the spring and the valve from the cover.

Inspection

Clean all of the regulator components in fuel oil and dry them with compressed air. Then inspect the parts for wear or damage. The regulator valve must move freely in the valve bore. If the valve is scored and cannot be cleaned up with crocus cloth, it must be replaced. Replace a fractured or pitted spring.

Install Oil Pressure Regulator

1. Apply clean engine oil to the outer surface of the valve and slide it into the opening in the engine lower front cover, closed end first.

2. Install a new copper gasket on the plug.

3. Insert the spring in the valve.

4. While compressing the spring, start the plug in the side of the cover, then tighten the plug.

LUBRICATING OIL FILTERS

Series 53 engines are equipped with a full-flow type lubricating oil filter. A bypass-type oil filter may be used in addition to the full-flow type filter when additional filtration is desired.

Full-Flow Oil Filter

The full-flow type lubricating oil filter (Fig. 1) is installed ahead of the oil cooler in the lubrication system. On the four-cylinder models, the oil filter may be mounted with the filter shell up, down, or toward the rear, except when on the blower side of the engine where the down and rearward positions are optional.

The filter assembly consists of a replaceable element enclosed within a shell which is mounted on an adaptor or base. When the filter shell is in place, the element is restrained from movement by a coil spring.

All of the oil supplied to the engine by the oil pump passes through the filter before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter base to the space surrounding the filter element. Impurities are filtered out as the oil is forced through the element to a central passage surrounding the center stud, out through another passage in the filter base, and then to the oil cooler.

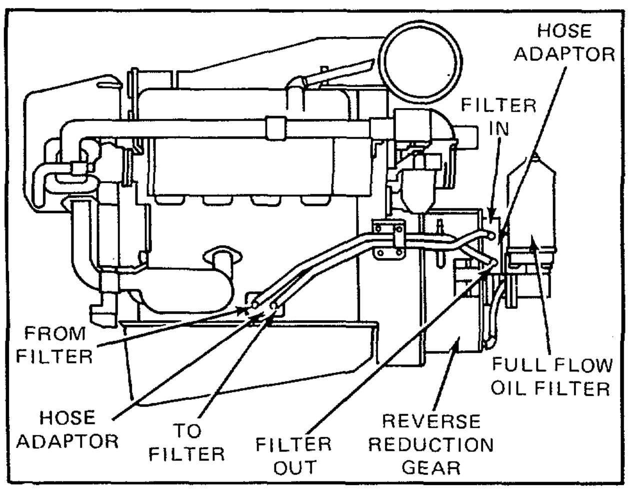


Figure 1. Proper Installation of Flexible Oil Filter Hoses

A valve, which opens at approximately 18-21 psi (124-145 kPa) is located in the filter base on engine-mounted filters or in the hose adaptor (7/8-inch hoses) with a remote mounted filter and will bypass the oil directly to the oil cooler should the filter become clogged.

Oil Filter Maintenance

With the use of detergent lubricating oils, the color of the lubricant has lost value as an indicator of oil cleanliness or proper filter action. Due to the ability of the detergent compounds to hold minute carbon particles in suspension, heavy-duty oils will always appear dark colored on the oil level dipstick.

Heavy sludge deposits found on the filter elements at the time of an oil change must be taken as an indication that the detergency of the oil has been exhausted. When this occurs, the oil drain interval should be shortened. The removal of abrasive dust, metal particles, and carbon must be ensured by replacement of the oil filter elements at the time the engine oil is changed.

Selection of a reliable oil supplier, strict observation of his oil change period recommendations, and proper filter maintenance will ensure trouble-free lubrication and longer engine life.

Replace Oil Filter Element

Replace the element in either the full- flow or bypass-type oil filter assembly (Fig. 2) as follows:

1. Remove the drain plug from the filter shell or the filter adaptor or base and drain the oil. If a type S-6 filter assembly is used, oil may be re- moved with a sump pump after the cover and element are removed.

2. Back out the center stud or the cover nut and withdraw the shell, element and stud as an assembly. Discard the element and the shell gasket.

3. Remove the center stud and gasket. Retain the gasket unless it is damaged and oil leaks occurred.

4. Remove the nut or snapring on the full-flow filter center stud.

NOTE

The center stud on the current full-flow oil filter has been revised by removing the snapring groove and increasing the 5/8-18 inch thread length approximately 1/2 inch. To conform with this change, a 5/8-18 inch nut replaces the snapring formerly used to retain the filter spring and seal.

5. Remove and discard the element retainer seal (Fig. 2). Install a new seal.

6. Clean the filter shell and the adaptor or base.

7. Install the center stud gasket and slide the stud (with the spring, washer, seal, and retainer installed on the full-flow filter) through the filter shell.

8. Install a new shell gasket in the filter adaptor or base.

CAUTION

Before installing the filter shell gasket, be sure all of the old gasket material is removed from the filter shell and the filter adaptor or base. Also make sure the gasket surfaces of the shell and the adaptor or base have no nicks, burrs, or other damage.

9. Position the new filter element carefully over the center stud and within the shell. Then place the shell, element, and stud assembly in position on the filter adaptor or base and tighten the stud to 50-60 lb ft (68-81 Nm) torque.

10. Install the drain plug.

11. Start and run the engine for a short period and check for oil leaks. After any oil leaks have been corrected and the engine has been stopped long enough (approximately 20 minutes) for the oil from various parts of the engine to drain back to the crankcase, add sufficient oil to bring it to the proper level on the dipstick.

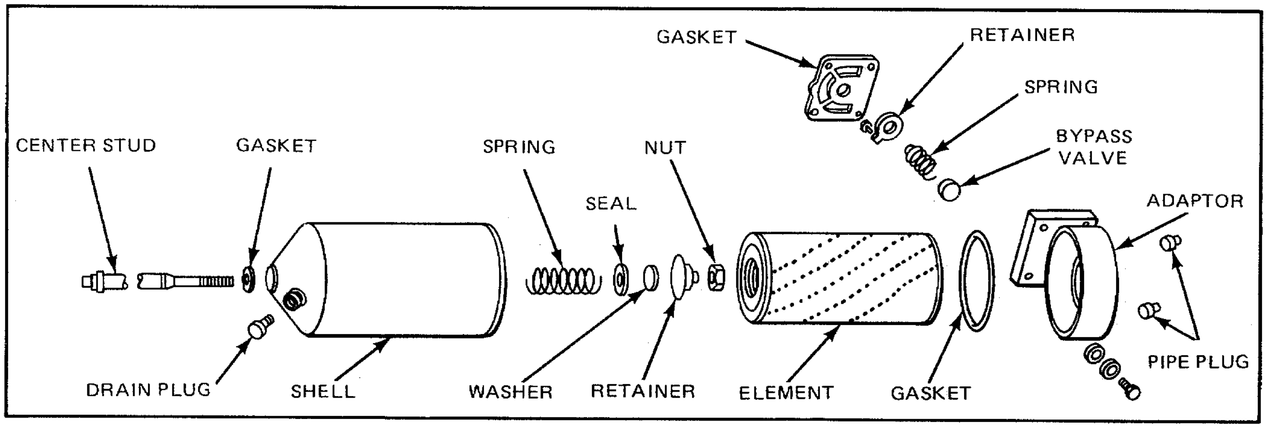


Figure 2. Full-Flow Oil Filter Details and Relative Location of Parts

LUBRICATING OIL COOLER

Engine oil coolers are provided for all engines. The oil cooler is mounted on the side of the cylinder block.

To assure engine lubrication should the oil cooler become plugged, a bypass valve located near the top of the lower engine front cover bypasses oil from the oil pump discharge port directly to the oil galleries in the cylinder block. The bypass valve opens at approximately 52 psi (359 kPa) (current in-line engines) or 30 psi (207 kPa) (former in-line engines). The valve components are the same as and serviced in the same manner as the oil pressure regulator valve in Lubricating Oil Pressure Regulator.

Coolant circulated through the oil cooler completely surrounds the oil cooler core. Therefore, whenever an oil cooler is assembled, special care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing on an in-line engine is attached to an oil cooler adaptor which, in turn, is attached to the cylinder block. The flow of oil is from the oil pump through a passage in the oil cooler adaptor to the full-flow oil filter, which is also mounted on the oil cooler adaptor, and then through the oil cooler core and the cylinder block oil galleries.

Remove Oil Cooler Core

1. Drain the cooling system by opening the draincock at the bottom of the oil cooler housing.

2. Remove any accessories or other equipment necessary to provide access to the cooler.

3. On in-line engines, loosen and slide the clamps and hose back on the water inlet elbow on the cylinder block.

4. Loosen and slide the clamps and hose back on the tube leading from the thermostat to the water pump.

5. Remove the bolts and lockwashers which attach the water pump to the oil cooler housing.

6. Matchmark the end of the oil cooler housing, cooler core and adaptor with a punch or file so they can be reinstalled in the same position.

7. Remove the bolts and lockwashers which attach the oil cooler housing to the adaptor or cylinder block and remove the housing and core as an assembly. Be careful when withdrawing the assembly not to drop or damage the cooler core.

8. If the adaptor is to be removed, the oil filter must first be removed. Then remove the bolts and lockwashers which attach the adaptor to the cylinder block. Withdraw the adaptor and gaskets.

9. Remove all traces of gasket material from the cylinder block and the oil cooler components.

Clean Oil Cooler Core

1. Clean oil side of Core - Remove the core from the oil cooler. Circulate a solution of trichloroethylene through the core passages with a force pump to remove the carbon and sludge.

WARNING

This operation should be done in the open or in a well ventilated room when trichloroethylene or other toxic chemicals are used for cleaning.

Clean the core before the sludge hardens. If the oil passages are badly clogged, circulate an Oakite or alkaline solution through the core and flush thoroughly with clean, hot water.

2. Clean water side of Cooler - After cleaning the oil side of the core, immerse it in the following solution: Add one-half pound of oxalic acid to each two and one-half gallons of solution composed of one-third muriatic acid and two-thirds water. The cleaning action is evidenced by bubbling and foaming. Watch the process carefully and, when bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution and thoroughly flush it with clean, hot water. After cleaning, dip the core in light oil.

CAUTION

Do not attempt to clean an oil cooler core when an engine failure occurs in which metal particles from worn or broken parts are released into the lubricating oil. Replace the oil cooler core.

Pressure Check Oil Cooler Core

After the oil cooler core has been cleaned, check for leaks as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to assure a tight seal. Drill and tap the plate to permit an air hose fitting to be attached at the inlet side of the core (Fig. 1).
2. Attach an air hose, apply approximately 75-150 psi (517-1034 kPa) air pressure and submerge the oil cooler core and plate assembly in a container of water heated to 180°F

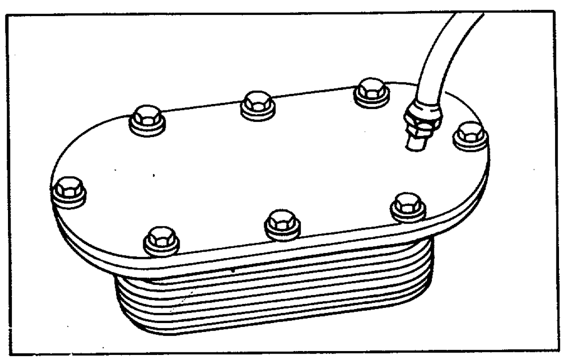


Figure 1. Preparing Oil Cooler Core for Pressure Test

(82°C). Any leaks will be indicated by air bubbles in the water. If leaks are indicated, replace the core.

WARNING

When making this pressure test, be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose, or the oil cooler core.

3. After the pressure check is completed, remove the plate and air hose from the cooler core, then dry the core with compressed air.

CAUTION

Where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent serious damage (refer to Cooling System).

Install Oil Cooler Core

1. If the oil cooler adaptor (in-line engines) was removed from the cylinder block, remove the old gasket material from the bosses where the adaptor sets against the block. Affix new adaptor gaskets (Fig. 2), then secure the adaptor to the cylinder block with five bolts and lockwashers.

2. Clean the old gasket material from both faces of the core flange and affix new gaskets to the inner and outer faces (Fig. 2). Insert the core into the cooler housing.

CAUTION

The inlet and outlet openings in the oil cooler core are stamped IN and OUT. It is very important that the core be installed in the correct position to prevent any possibility of foreign particles and sludge, which may not have been removed in cleaning the fins of the core, entering and circulating through the engine.

3. Align the matchmarks previously placed on the core and housing and install the oil cooler core in the oil cooler housing.

4. With the matchmarks in alignment, place the oil cooler housing and core against the oil cooler adaptor. Then secure the housing in place with bolts and lockwashers. Tighten the bolts to 13-17 lb ft (18-23 Nm) torque.

5. Slide the hose and clamps in position between the cylinder block water inlet elbow and the oil cooler. Secure the clamps in place.

6. Place a new gasket between the water pump and the cooler housing and secure the pump to the cooler housing.

7. Position the hose and clamps in place between the water pump and the tube to the thermostat housing. Secure the clamps.

8. Install all of the accessories or equipment it was necessary to remove.

9. Reinstall the oil filter (in-line engine).

10. Make sure the draincock in the bottom of the cooler housing is closed. Then fill the cooling system to the proper level.

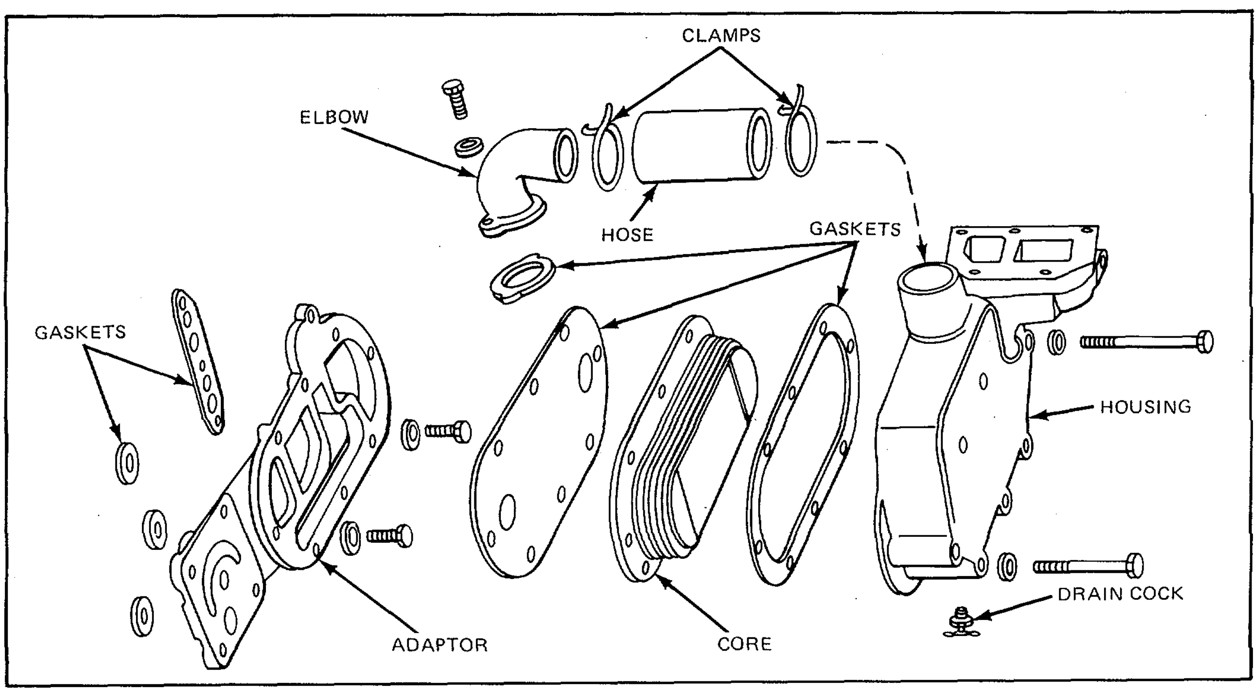


Figure 2. Oil Cooler Details and Relative Location of Parts

OIL LEVEL DIPSTICK

A steel ribbon-type oil level dipstick is mounted in an adaptor on the side of the engine (Fig. 1) to check the amount of oil in the engine oil pan. The dip- stick has markings to indicate the low and full oil level. Current engines include a 3/4-inch long rubber oil seal inside the cap of the dipstick. This prevents the escape of vapors carrying oil from the dipstick tube.

Maintain the oil level between the full and low marks on the dipstick and never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Over-filling will cause the oil to be churned by the crankshaft throws causing foaming or aereation of the oil. Operation below the low mark will expose the pump pick-up causing aereation and/or loss of pressure.

Check the oil level after the engine has been stopped for a minimum of twenty minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface.

Improper oil levels can result if the oil level is checked with the equipment on a grade.

Fill the crankcase with oil as follows:

1 . Fill the oil pan to the fu1l mark on the dipstick.

2. Start and run the engine for approximately ten minutes.

3. Stop the engine and wait a minimum of twenty minutes. Then add the required amount of oil to reach the full mark on the dipstick.

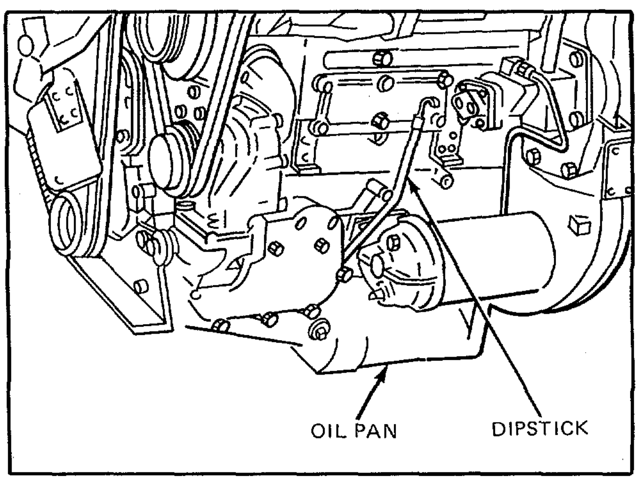


Figure 1. Typical Oil Dipstick Mounting

OIL PAN

The oil pan (Fig. 1) may be made of steel, cast iron, or cast aluminum. A shallow or deep sump-type oil pan is used, depending upon the particular engine application. A one-piece oil pan gasket is used with stamped steel pans. A four-piece gasket is used with the cast oil pans.

Removing and Installing Oil Pan

On some engine applications, it may be possible to remove the oil pan without removing the engine. It is recommended that if the engine is to be removed, the oil pan be left in place until the engine is removed.
The procedure for removing the oil pan without taking the engine out and after taking the engine out of the unit will vary. However, the following will generally apply.

1. Remove the drain plug and drain the oil.

2. Detach the oil pan; take precautions to avoid damaging the oil pump inlet pipe and screen.

3. Remove the oil pan gasket completely.

4. Clean all of the old gasket material from the cylinder block and the oil pan. Clean the oil pan with a suitable solvent and dry it with compressed air.

5. Inspect a cast oil pan for porosity or cracks. Check a stamped oil pan for dents or breaks in the metal which may necessitate repair or replacement. Check for misaligned flanges or raised surfaces surrounding the boltholes by placing the pan on a surface plate or other large, flat surface.

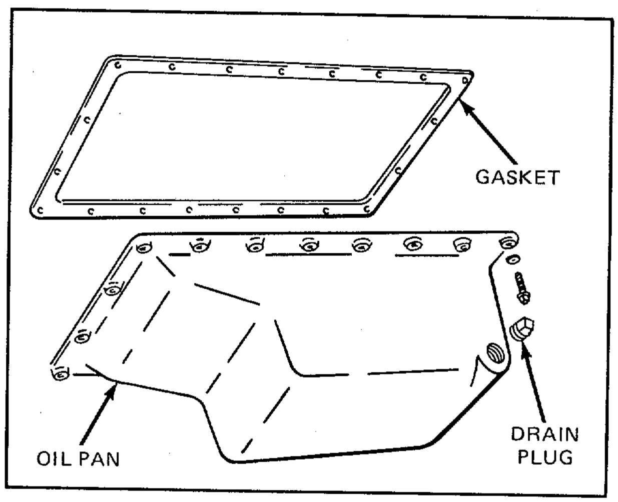


Figure 1. Typical Oil Pan

6. When installing the oil pan, use a new gasket and, starting with the center bolt on each side and working alternately toward each end of the pan, tighten the bolts to 10-20 lb ft (14-27 Nm) torque. DO NOT overtighten the bolts. Once the bolts are tightened to the specified torque, do not retighten them as it could be detrimental to the current-type gaskets. If a leak should develop at the oil pan, check if the lockwasher is compressed. If not, the bolt may be tightened. However, if the lockwasher is compressed and leaking occurs, remove the oil pan and determine the cause of the leakage.

NOTE

Current oil pan bolts (stamped metal pans) are coated with a locking material. To reactivate the locking ability of the bolts, apply a drop or two of Loctite J 26558-242, or equivalent, to the threads of the bolts at reassembly.

7. Install and tighten the oil drain plug. Tighten the plug (with nylon washer) to 25-35 lb ft (34-47 Nm) torque.

8. Fill the oil pan with new oil (refer to *Oil Level Dipstick* and *Fuel and Oil Specifications*) to the full mark on the dipstick. Then start and run the engine for ten minutes and check for oil leaks.

9. Stop the engine and, after approximately twenty minutes, check the oil level. Add oil if necessary

VENTILATING SYSTEM

Harmful vapors which may be formed within the engine are removed from the crankcase, gear train, and valve compartment by a continuous pressurized ventilating system.

A slight pressure is maintained in the engine crankcase by the seepage of a small amount of air from the airbox past the piston rings. This air sweeps up through the engine and is drawn off through a crankcase breather.

In-line engines are equipped with a breather assembly attached to the valve rocker cover (Fig. 1) or a breather assembly mounted on the flywheel housing (Fig. 2).

Service

It is recommended that the breather tube be inspected and cleaned, if necessary, to eliminate the possibility

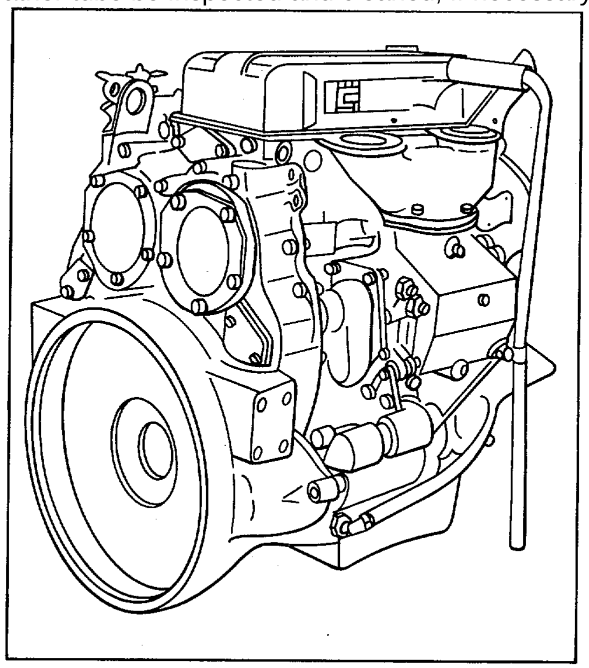


Figure 1. Typical Crankcase Breather Mounting

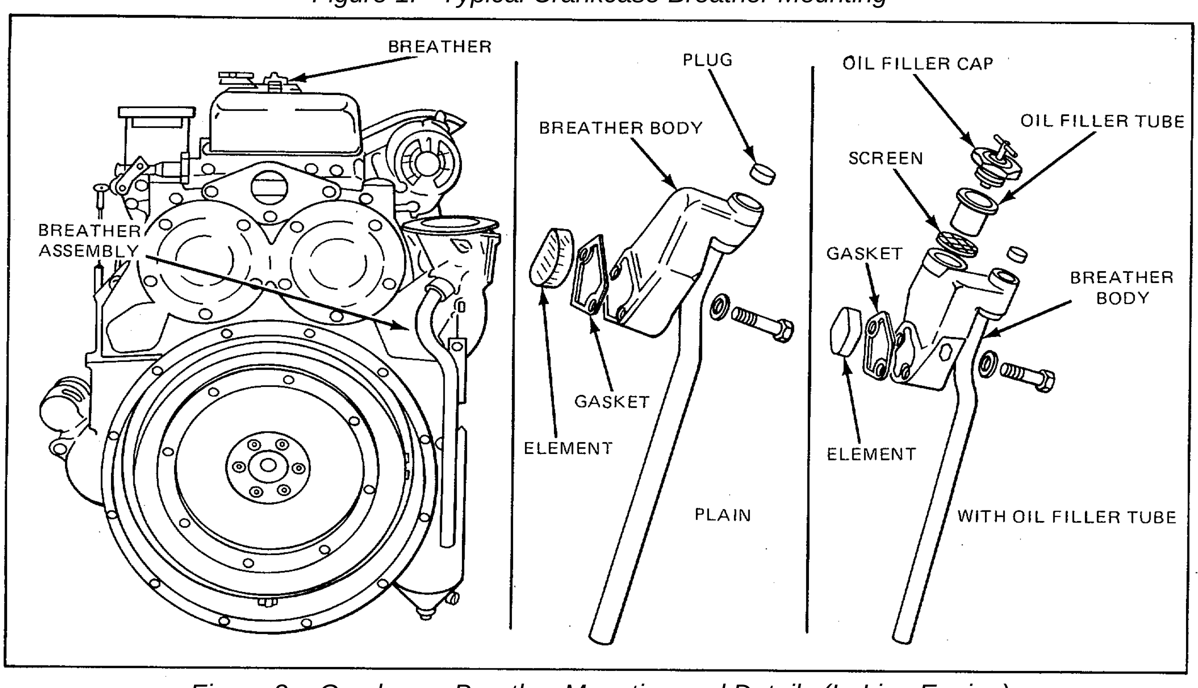


Figure 2. Crankcase Breather Mounting and Details (In-Line Engine)

of clogging. This can best be done by removing the tube from the engine, washing it with a suitable solvent, and drying it with compressed air.

The wire mesh pad (element) in the breather assemblies should be cleaned if excessive crankcase pressure is observed.

If it is necessary to clean the element, remove the breather housing from the flywheel housing. Wash the element in fuel oil and dry it with compressed air.

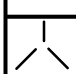
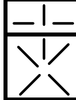
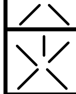
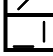
Reinstall the element in the breather housing, the upper front cover or the governor housing, and/or the valve rocker cover and install them by reversing the procedure for removal.

LUBRICANT SYSTEM - SPECIFICATIONS - SERVICE TOOLS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb ft)	(Nm)	THREAD SIZE	280M OR BETTER TORQUE (lb ft)	(Nm)
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	810	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designatio n	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM-260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
 Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
 Hex Head Sems Only	GM-275-M	5.1	No. 6 thru 3/8	120,000
 Bolts and Screws	BM 290-M	7	1/4 thru 1 1/2	133,000
 Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
 Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Oil pan bolts	5/16-18	10-20	14-27
Oil filter center stud	5/8-18	50-60	68-81
Oil pan drain plug (Nylon washer)	18 mm	25-35	34-47

SERVICE TOOLS

TOOL NAME	TOOL NO.
Crankshaft pulley installer set	J 7773
Oil pump drive gear adapter	J 23126
Oil pump drive gear installer	J 8968-01
Strap wrench (spin-on filter	J 24783
Universal puller (4-inch-diameter range	J 24420
Universal puller (13-inch-diameter range	J 8190

COOLING SYSTEM

To effectively dissipate the heat generated by the engine, a radiator and fan is used. A centrifugal-type water pump is used to circulate the engine coolant in the system. It incorporates thermostats to maintain a normal operating temperature of 160-185°F (71-850C). The engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block.

From the cylinder block, the coolant passes up through the cylinder head(s) and, when the engine is at normal operating temperature, through the thermostat housing(s) and into the upper portion of the radiator. Then the coolant passes down a series of tubes where the coolant temperature is lowered by the air stream created by the revolving fan.

Upon starting a cold engine or when the coolant is below operating temperature, the coolant is restricted at the thermostat housing and a bypass provides water circulation within the engine during the warm-up period.

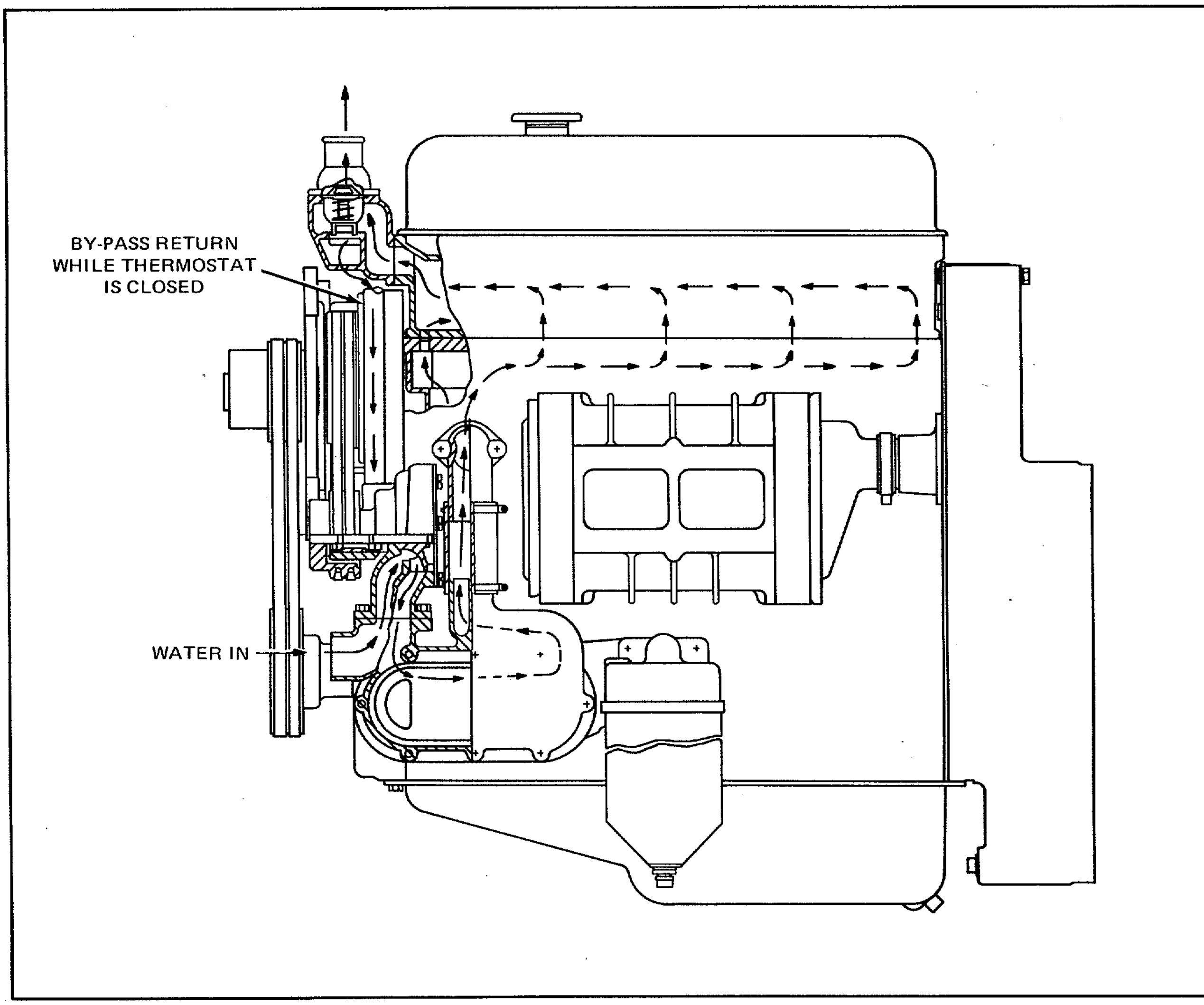


Figure 1. Typical Cooling System for an In-Line Engine

ENGINE COOLING SYSTEM MAINTENANCE

Engine Coolant

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as exhaust valves, cylinder liners, and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant when oil-to-water oil coolers are used. Refer to *Fuel and Oil Specifications* for coolant recommendations.

Cooling System Capacity

The capacity of the basic engine cooling system (cylinder block, head, thermostat housing, and oil cooler housing) is shown in Table 1.

To obtain the complete amount of coolant in the cooling system of a unit, the additional capacity of the radiator, hoses, etc. must be added to the capacity of the basic engine. The capacity of the radiator and related equipment should be obtained from the equipment supplier, or the capacity of a particular cooling system may be determined by filling the system with water, then draining and measuring the amount required.

TABLE 1

COOLING SYSTEM CAPACITY (BASIC ENGINE)		
ENGINE	CAPACITY	
	GALLONS	LITRES
4-53	2-1/4	8.5

Fill Cooling System

Before starting the engine, close all of the draincocks and fill the cooling system with water. The use of clean, soft water will eliminate the need for descaling solutions to clean the cooling system. A hard mineral-laden water should be made soft by using water softener chemicals before it is poured into the cooling system. These water softeners modify the minerals in the water and greatly reduce or eliminate the formation of scale. Refer to *Engine Coolant*.

Start the engine and, after normal operating temperature has been reached allowing the coolant to expand to its maximum, check the coolant level. The coolant level should be within two inches of the filler neck.

Excessive amounts of air in the cooling system may hinder the flow of water due to pump cavitation or result in hot spots when air collects at low velocity points in the water passages. Therefore, whenever the cooling system is filled or makeup water is added, the air must be thoroughly vented from the system. The thermostat housing on the Series 53 engines provides a venthole to release the air to the atmosphere while the cooling system is being filled. In addition, the cooling system should be vented at the time normal operating temperature is reached after starting the engine and again after the engine has been in operation for 30 to 45 minutes.

Should a daily loss of coolant be observed, and there are no apparent leaks, there is a possibility of gases leaking past the cylinder head water seal rings into the cooling system. The presence of air or gases in the cooling system may be detected by connecting a rubber tube from the overflow pipe to a water container. Bubbles in the water in the container during engine operation will indicate this leakage. Another method for observing air in the cooling system is by inserting a transparent tube in the water-outlet line.

Drain Cooling System
Drain the cooling system by opening the cylinder block and radiator (or heat exchanger) draincocks and removing the cooling system filler cap. Removal of the filler cap permits air to enter the cooling passages and the coolant to drain completely from the system.

Draincocks are located as indicated in Table 2. Radiators that do not have a draincock are drained through the oil cooler housing drain.

If freezing weather is anticipated and the engine is not protected by antifreeze, drain the cooling system completely when the engine is not in use. Leave all of the draincocks open until the cooling system is refilled. Should any entrapped water in the cylinder block, radiator, or other engine parts freeze, it will expand and may result in damage to the engine.

TABLE 2

COOLANT DRAIN VALVES

Engine	Oil Cooler or Coolant Inlet Side of Block	Side of Block Opposite Oil Cooler or Coolant Inlet
4-53	Bottom of oil cooler, coolant inlet, and behind blower drive or governor near rear of block	Behind blower drive or governor near rear of block

Flushing
If a coolant filter is used and properly maintained, the cooling system need not be flushed. Otherwise, the cooling system should be flushed each spring and fall. The flushing operation cleans the system of antifreeze solution in the spring and removes the summer rust inhibitor in the fall, cleaning the system for the next solution. The flushing operation should be performed as follows:

1. Drain the previous season's solution from the engine.

2. Refill with soft, clean water.

CAUTION

If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes to thoroughly circulate the water.

4. Drain the unit completely.

5. Refill with the solution required for the coming season.

Cooling System Cleaners
If the engine overheats, and the fan belt tension and water level have been found to be satisfactory, clean and flush the entire cooling system. Remove scale formation by using a reputable and safe descaling solvent. Immediately after using the descaling solvent, neutralize the system with the neutralizer. It is important that the directions printed on the container of the descaler be thoroughly read and followed.

After the solvent and neutralizer have been used, completely drain the engine and radiator and reverse-flush before filling the system.

Reverse-Flushing
After the engine and radiator have been thoroughly cleaned, they should be reverse-flushed. The water pump should be removed and the radiator and engine reverse-flushed separately to prevent dirt and scale deposits clogging the radiator tubes or being forced through

the pump. Reverse-flushing is accomplished by hot water, under air pressure, being forced through the cooling system in a direction opposite to the normal flow of coolant, loosening and forcing scale deposits out.

The radiator is reverse-flushed as follows:

1. Remove the radiator inlet and outlet hoses and replace the radiator cap.

2. Attach a hose at the top of the radiator to lead water away from the engine.

3. Attach a hose to the bottom of the radiator and insert a flushing gun in the hose.

4. Connect the water hose of the gun to the water outlet and the airhose to the compressed air outlet.

5. Turn on the water and, when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between airblasts.

CAUTION

Apply air gradually. Do not exert more than 30 psi (207 kPa) air pressure. Too great a pressure may rupture a radiator tube.

6. Continue flushing until only clean water is expelled from the radiator.

The cylinder block and cylinder head water passages are reverse-flushed as follows:

1. Remove the thermostats and the water pump.

2. Attach a hose to the water inlet of the cylinder block to drain the water away from the engine.

3. Attach a hose to the water outlet at the top of the cylinder block and insert the flushing gun in the hose.

4. Turn on the water and, when the water jackets are filled, turn on the air in short blasts, allowing the engine to fill with water between airblasts.

5. Continue flushing until the water from the engine runs clean.

If scale deposits in the radiator cannot be removed by chemical cleaners or reverse-flushing as outlined above, it may be necessary to remove the upper tank and rod out the individual radiator tubes with flat steel rods. Circulate water through the radiator core from the bottom to the top during this operation.

Miscellaneous Cooling System Checks

In addition to the above cleaning procedures, the other components of the cooling system should be checked periodically to keep the engine operating at peak efficiency. The cooling system hoses, thermostats, and radiator pressure cap should be checked and replaced if found to be defective.

When water connection seals and hoses are installed, be sure the connecting parts are properly aligned and the seal or hose is in its proper position before tightening the clamps. All external leaks should be corrected as soon as detected.

The fan belt must be checked and adjusted, if necessary, to provide the proper tension and the fan shroud must be tight against the radiator core to prevent recirculation of air which may lower the cooling efficiency.

Contaminated Engines

When the engine cooling or lubricating system becomes contaminated, it should be flushed thoroughly to remove the contaminants before the engine is seriously damaged. One possible cause of such contamination, that is damaging to the engine if it is not corrected immediately, is a cracked oil cooler core. With a cracked oil cooler core, oil will be forced into the cooling system while the engine is operating, and when it is stopped, coolant will leak into the lubricating system.

Coolant contamination of the lubricating system is especially harmful to engines during the cold season when the cooling system is normally filled with an ethylene glycol antifreeze solution. If mixed with the oil in the crankcase, this antifreeze forms a varnish which quickly immobilizes moving engine parts.

To remove such contaminants from the engine, both the cooling system and the lubrication system must be thoroughly flushed as follows:

COOLING SYSTEM

If the engine has had a failure resulting in the contamination of the cooling system with lubricating oil, the following procedure is recommended.

1. Prepare a mixture of Calgon, or equivalent, and water at the rate of two ounces (dry measure) to one gallon of water.

2. Remove the engine thermostats to permit the Calgon and water mixture to circulate through the engine and the radiator or heat exchanger.

3. Fill the cooling system with the Calgon solution.

4. Run the engine for five minutes.

5. Drain the cooling system.

6. Repeat Steps 3 through 5.

7. Fill the cooling system with clean water.

8. Let the engine run five minutes.

9. Drain the cooling system completely.

10. Install the engine thermostat.

11. Close all of the drains and refill the engine with fresh coolant.

LUBRICATION SYSTEM

When the engine lubricating system has been contaminated by an ethylene glycol antifreeze solution or other soluble material, the following cleaning procedure, using Butyl Cellosolve, or equivalent, is recommended.

WARNING

Use extreme care in the handling of these chemicals to prevent serious injury to the person or damage to finished surfaces. Wash off spilled fluid immediately with clean water.

If the engine is still in running condition, proceed as follows:

1. Drain all of the lubricating oil.

2. Remove and discard the oil filter element. Clean and dry the filter shell and replace the element.

3. Mix two parts of Butyl Cellosolve, or equivalent, with one part SAE 1O engine oil. Fill the engine crankcase to the proper operating level with the mixture.

4. Start and run the engine at a fast idle (1,000 to 1,200 rpm) for 30 minutes to one hour. Check the oil pressure frequently.

5. After the specified time, stop the engine and immediately drain the crankcase and the filter. Sufficient time must be allowed to drain all of the fluid.

6. Refill the crankcase with SAE 10 oil after the drain plugs are replaced. Run the engine at the same fast idle for ten or fifteen minutes and again drain the oil thoroughly.

7. Remove and discard the oil filter element, clean the filter shell and install a new element.

8. Replace the drains and fill the crankcase to the proper level with the oil recommended for normal engine operation.

9. To test the effectiveness of the cleaning procedure, it is recommended that the engine be started and run at a fast idle (1,000 to 1,200 rpm) for approximately 30 minutes. Then stop and immediately restart the engine. There is a possibility that the engine is not entirely free of contaminant deposits if the starting speed is slow.

10. If the procedures for cleaning the lubricating oil system were not successful, it will be necessary to disassemble the engine and to clean the affected parts thoroughly.

CAUTION

Make certain that the cause of the internal coolant leak has been corrected before returning the engine to service.

WATER PUMP

A centrifugal-type water pump (Fig. 1) is mounted on top of the engine oil cooler housing as shown in Fig. 2. It circulates the coolant through the oil cooler, cylinder block, cylinder head, and radiator.

The pump is belt-driven by either the camshaft or balance shaft.

An impeller is pressed onto one end of the water pump shaft, and a water pump drive pulley is pressed onto the opposite end. The pump shaft is supported on a sealed double-row combination radial and thrust ball bearing. Coolant is prevented from creeping along the shaft toward the bearing by a seal. The shaft and bearing constitute an assembly and are serviced as such, since the shaft serves as the inner race of the ball bearing.

The sealed water pump shaft ball bearing is filled with lubricant when assembled. No further lubrication is required.

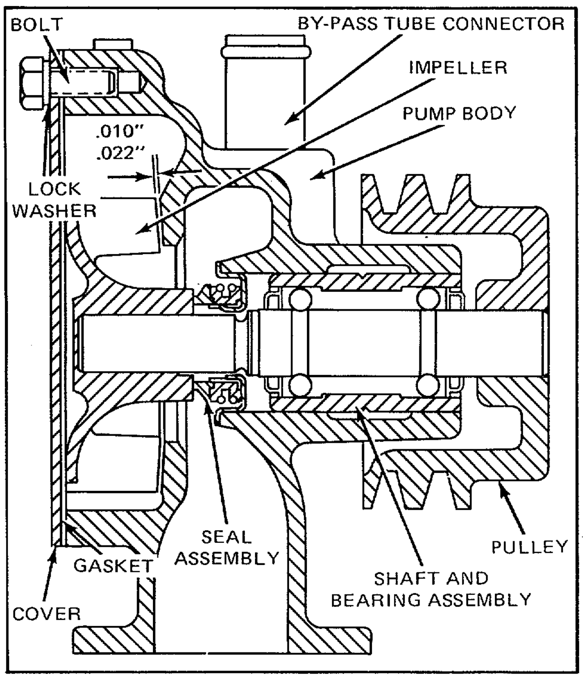


Figure 1. Water Pump Assembly

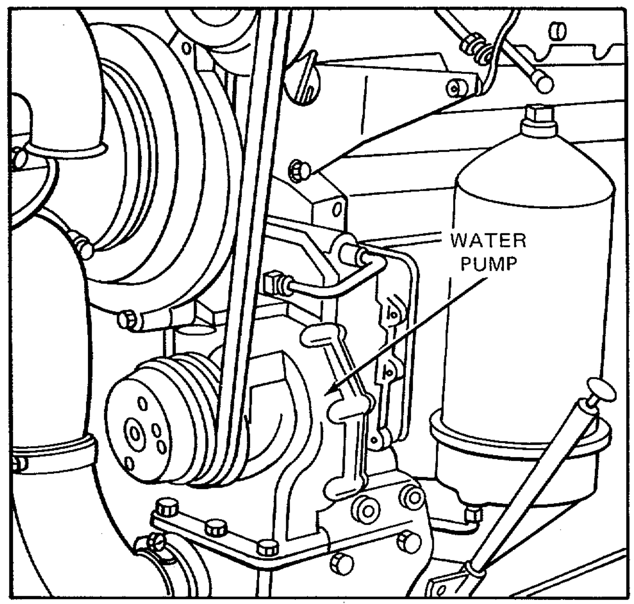


Figure 2. Typical Water Pump Mounting

Remove Water Pump

1. Remove the radiator cap, open the block and radiator draincocks, and drain the cooling system.

2. Loosen and remove the water pump belts.

NOTE

An idler pulley is used on some engines to adjust the water pump drive belt tension.

3. Loosen the hose clamps and slide the hose up on the water bypass tube.

4. Remove the five bolts securing the water pump to the oil cooler housing and take off the pump.

Disassemble Pump

1. Note the position of the pulley on the shaft so that the pulley can be reinstalled in the same position when the pump is reassembled. Remove the water pump pulley as shown in Fig. 3.

2. Remove the pump cover and discard the gasket.

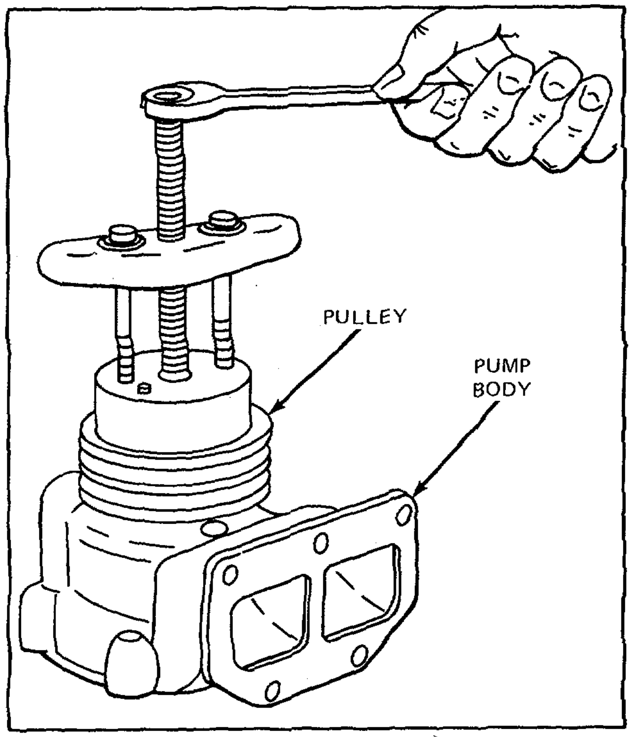


Figure 3. Removing Pulley

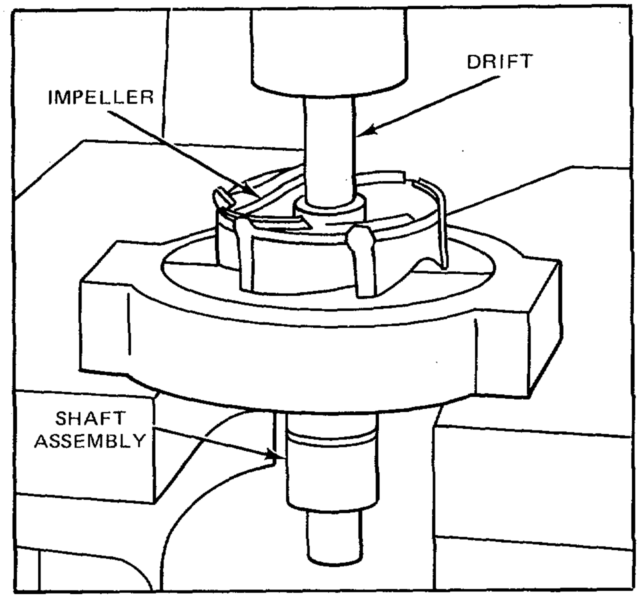


Figure 4. Removing Shaft from Impeller with Tools J 8329 and J 358-1

3. Press the shaft and bearing assembly, seal, and impeller out of the pump body as an assembly by applying pressure on the bearing outer race with remover J 1930.

CAUTION

The bearing will be damaged if the pump is disassembled by pressing on the end of the pump shaft.

4. Press the end of the shaft out of the impeller as shown in Fig. 4, using plates J 8329 and holder J 358-1.

5. Remove the seal assembly from the pump shaft and discard it.

Inspection

Wash all of the pump parts, except the bearing and shaft assembly, in clean fuel oil and dry them with compressed air.

CAUTION

A permanently sealed and lubricated bearing is used in the bearing and shaft assembly and should not be washed. Wipe the bearing and shaft assembly with a clean, lintless cloth.

Examine the impeller for damage and excessive wear on the impeller face which contacts the seal. Replace the impeller if it is worn or damaged.

Discard the bearing if it has a general feeling of roughness, is tight or has indications of damage.

Assemble Pump

1. Use installer J 1930 to apply pressure to the outer race of the bearing as shown in Fig. 5 and press the shaft and bearing assembly into the pump body until the outer race of the bearing is flush with the outer face of the body.

CAUTION

The bearing will be damaged if the bearing and shaft assembly is installed by applying pressure on the end of the shaft.

2. Lightly coat the outside diameter of the new seal with sealing compound. Then, with the face of the body and the bearing outer race supported, install the seal by applying pressure on the seal outer flange only, until the flange contacts the body (Fig. 1). Wipe the face of the seal with a chamois to remove all dirt and metal particles.

3. Support the pulley end of the shaft on the bed of an arbor press and press the impeller on the shaft until the impeller is flush with the large end of the body.

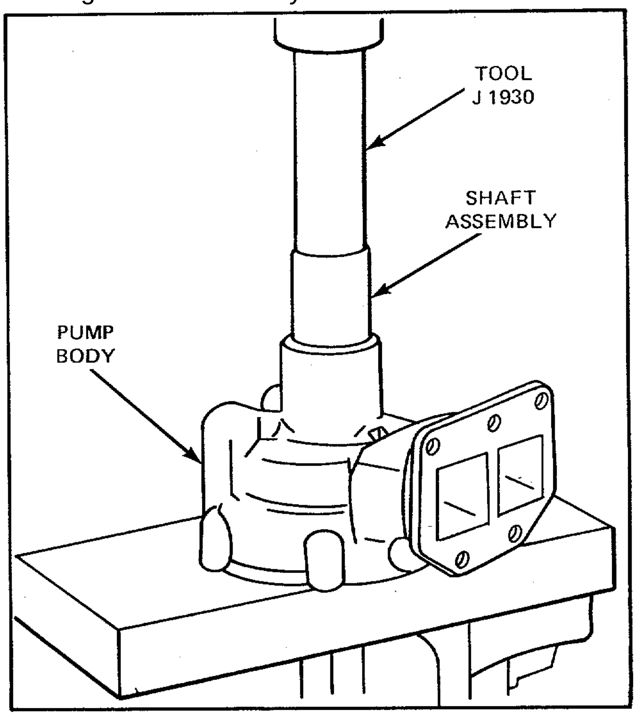


Figure 5. Pressing Shaft Assembly into Water Pump

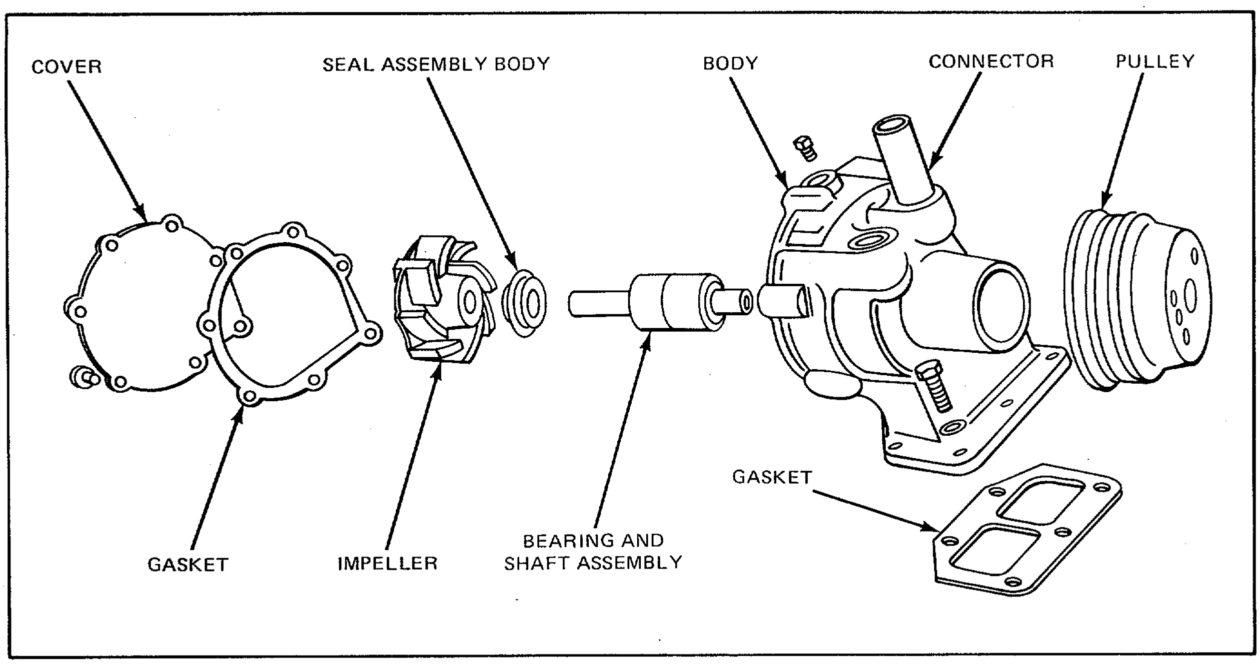


Figure 6. Fresh Water Pump Details and Relative Location of Parts

4. Place the pulley on the bed of an arbor press. Place a suitable rod between the ram of the press and the impeller end of the shaft, then press the shaft into the pulley until the pulley is in its original position on the shaft.

5. Install the cover and a new gasket on the pump body. Tighten the cover bolts to 6-7 lb ft torque.

6. Run the pump dry at 1200 rpm for a minimum of 30 seconds, or as required, to assure satisfactory seating of the seal.

Install Water Pump

1. Affix a new gasket to the flange of the water pump body.

2. Secure the water pump to the oil cooler housing with the five bolts and lockwashers.

3. Install the hose between the water pump and water bypass tube and tighten the hose clamps.

4. Install and tighten the belts.

NOTE

An idler pulley is used on some engines to adjust the water pump drive belt tension.

5. Close all of the draincocks and refill the cooling system.

6. Start the engine and check for leaks.

WATER PUMP IDLER PULLEY ASSEMBLY

The water pump idler pulley assembly is mounted on the upper engine front cover (Fig. 1).

Remove Idler Pulley Assembly

Remove the two attaching bolts and lift the pulley assembly away from the front cover and drive belts.

Disassemble Idler Pulley Assembly

1. Support the pulley, then press the shaft and bearing assembly and bracket from the pulley by applying pressure to the outer race of the bearing (Fig. 2).

2. Support the bracket, then press the shaft and bearing assembly from the idler pulley bracket by applying pressure on the shaft only.

Inspection

Wash the idler pulley bracket and pulley in clean fuel oil and dry them with compressed air. The idler pulley shaft and bearing assembly must not be washed in fuel oil. If the bearing is immersed in cleaning fluid, dirt may be washed in and the fluid and dirt could not be entirely removed from the bearing.

Examine the bracket and pulley for excessive wear or cracks.

Revolve the shaft slowly in the bearing by hand. If rough or tight spots are detected, the bearing and shaft assembly must be replaced.

On early engines, if the bracket or bearing assembly requires replacement, the complete idler pulley assembly must be replaced. The bearing bore diameter on the current bracket is 0.6237-0.6247 inch. On the former bracket, the bearing bore diameter is 0.6242-0.6252 inch.

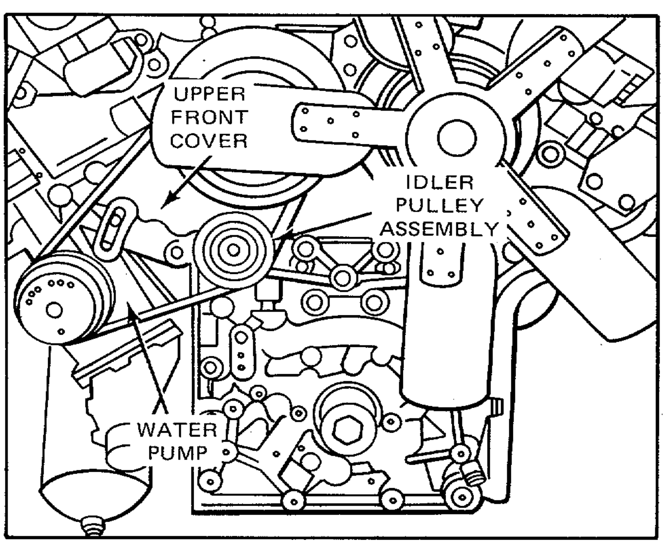


Figure 1. Typical Fresh Water Pump Idler Pulley Mounting

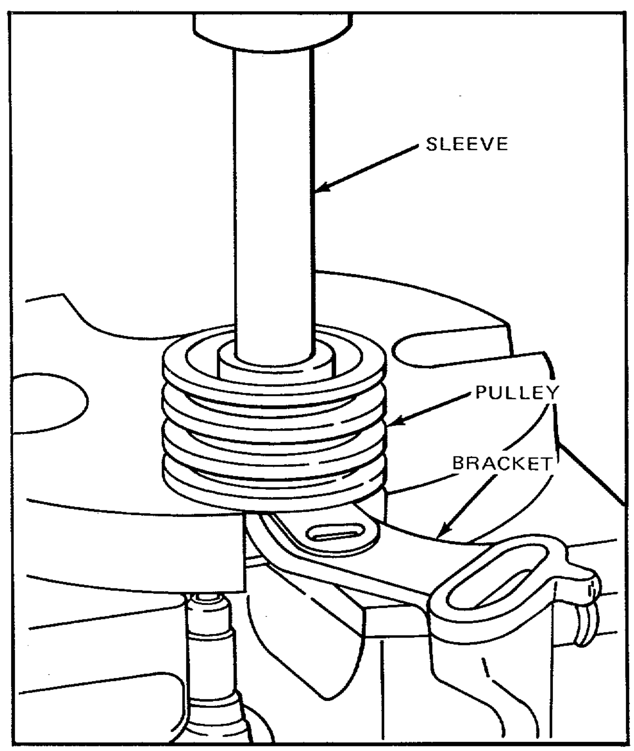


Figure 2. Removing Shaft and Bearing Assembly and Bracket from Idler Pulley

Assemble Idler Pulley Assembly

1. Apply a minimum of 2500 lbs pressure only on the outer race of the bearing as shown in Fig. 3 and press the bearing and shaft assembly into the idler pulley until the outer race of the bearing is flush with the inside surface of the pulley.

2. With a short rod, apply pressure on the shaft only (Fig. 4) and press the shaft and bearing assembly with the pulley into the idler pulley bracket. The distance between the outer edge of the pulley and the bracket must be 0.160 inch.

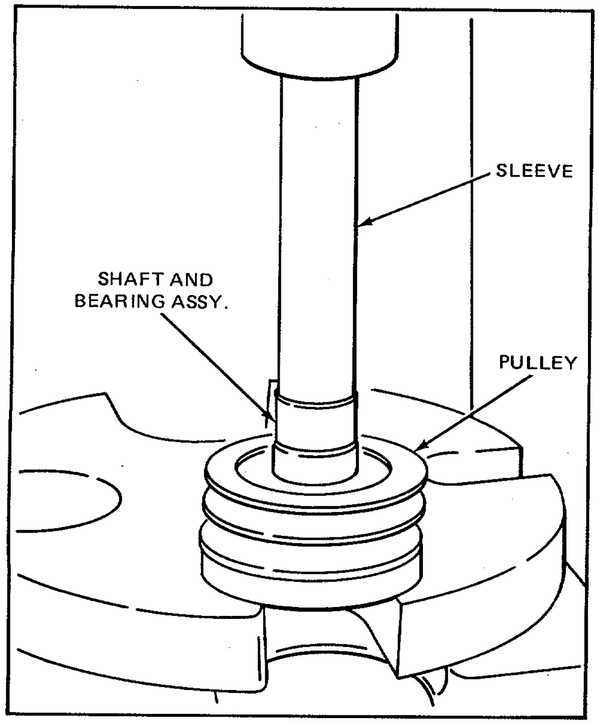


Figure 3. Installing Shaft and Bearing Assembly in Idler Pulley

Install Idler Pulley Assembly

1. Attach the idler pulley assembly to the front cover with two bolts and lockwashers.

2. Install the water pump drive belts.

3. Adjust the idler pulley assembly so that the drive belts have the proper tension and tighten the bolts.

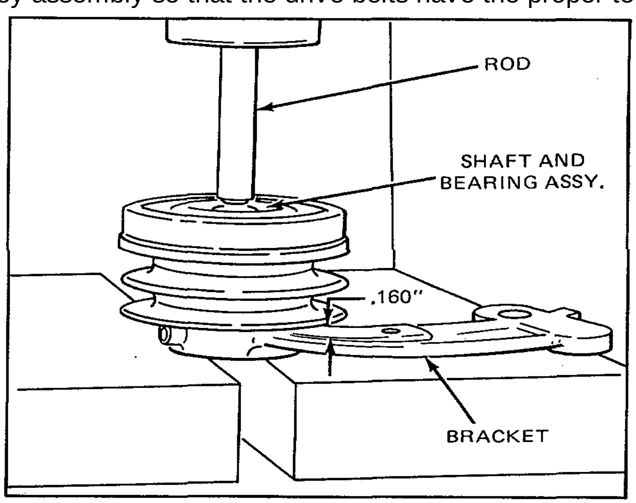


Figure 4. Installing Shaft and Bearing Assembly and Pulley in Bracket

THERMOSTAT

The temperature of the engine coolant is automatically controlled by a blocking-type thermostat located in a housing attached to the water outlet end of the cylinder head. A single thermostat is used in the in-line engines.

At coolant temperatures below approximately 170°F (77°C), the thermostat valve remains closed and blocks the flow of coolant through the radiator. During this period, the coolant circulates through the cylinder block and head and then back to the suction-side of the pump via the bypass tube. As the coolant temperature rises, the thermostat valve begins to open, restricting the bypass system and permits the coolant to circulate through the radiator. However, with the valve fully opened in the in-line engine, a very small portion of the coolant will continue to circulate through the by-pass tube, while the major portion will pass through the radiator. A properly operating thermostat is essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 160-185°F (71-85°C), remove and check the thermostat.

Remove Thermostat

1. Drain the cooling system to the necessary level by opening the drain valves.

2. Remove the hose connections between the thermostat housing water-outlet elbow and the radiator or heat exchanger.

3. Loosen the bolts and remove the water-outlet elbow from the thermostat housing on the in-line engine (Fig. 1). Take out the thermostat.

Inspection

If the action of the thermostat has become impaired due to accumulated rust

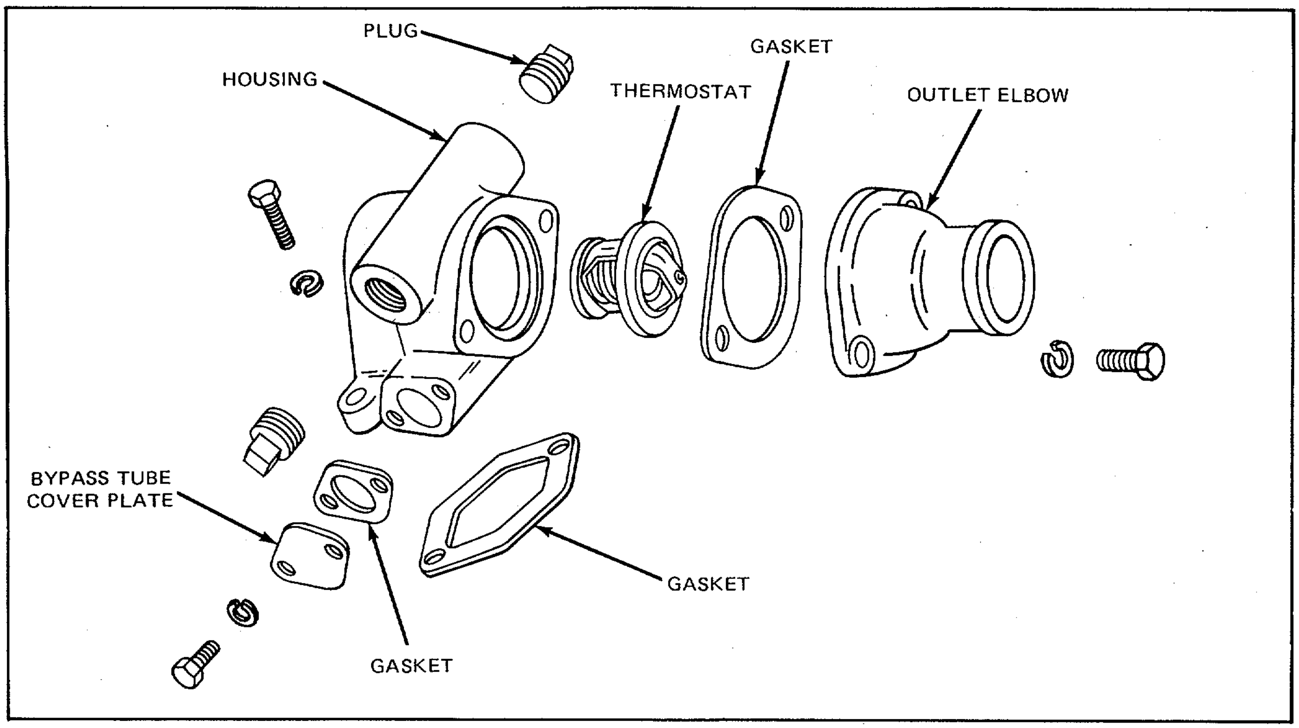


Figure 1. Thermostat Housing Details and Relative Location of Parts

and corrosion from the engine coolant so that it remains closed, or only partially open, thereby restricting the flow of water, overheating of the engine will result. A thermostat which is stuck in a wide open position may not permit the engine to reach its normal operating temperature. The incomplete combustion of fuel due to cold operation will result in a buildup of carbon deposits on the pistons, rings, and valves.

The operation of the thermostat may be checked by immersing it in a container of hot water (Fig. 2). Place a thermometer in the container, but do not allow it to touch the bottom. Agitate the water to maintain an even temperature throughout the container. As the water is heated, the thermostat valve should begin to open when the temperature reaches 167-172°F (75-78°C). The opening temperature is usually stamped on the thermostat. The thermostat should be fully open at approximately 190-192°F(88-89°C).

Clean the thermostat seating surface in the thermostat housing and base or the water outlet elbow.

Check the bleed hole in the thermostat housing to be sure it is open.

Drill a 3/32-inch diameter hole in the thermostat housing used on in-line industrial engines built prior to serial number 4D-094 (refer to Fig. 3). This will provide a coolant drain hole for the bypass cavity in the housing.

Install Thermostat

Refer to Fig. 1 and install the thermostat as follows:

IN-LINE ENGINE:

1. Place a new gasket on the thermostat housing.

2. Insert the thermostat into the housing.

3. Install the water outlet elbow and secure it to the housing with two bolts and lockwashers.

4. Connect the hose from the radiator or heat exchanger to the water outlet elbow, align and tighten the hose clamps.

After the thermostat has been installed, close all of the draincocks and fill the cooling system. Vent the system as outlined in *Cooling System*. Then start the engine and check for leaks.

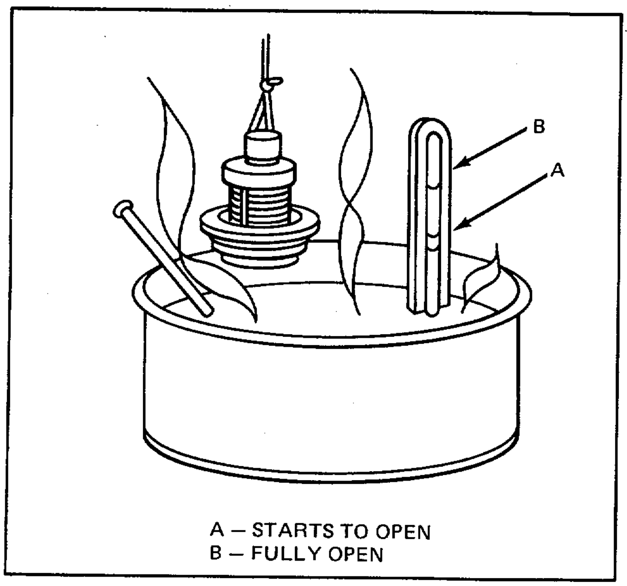


Figure 2. Checking Thermostat Operation

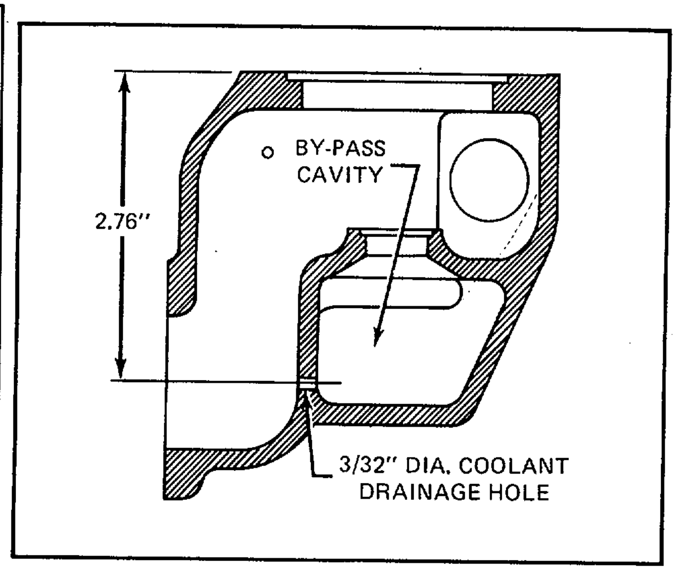


Figure 3. Cross-Section of Thermostat Housing

RADIATOR

The temperature of the coolant circulating through the engine is lowered by the action of the radiator and the fan. The radiator is mounted in front of the engine so that the fan will draw air through it, thereby lowering and maintaining the coolant temperature to the degree necessary for efficient engine operation. Typical Radiator Mounting (Fig. 1).

The life of the radiator will be considerably prolonged if a recommended-type coolant is used (refer to *Coolant Specifications).*

To increase the cooling efficiency of the radiator, a metal shroud is placed around the fan. The fan shroud must be fitted airtight against the radiator to prevent recirculation of the hot air drawn through the radiator. Hot air which is permitted to pass around the sides or bottom of the radiator and is again drawn through the radiator will cause overheating of the engine.

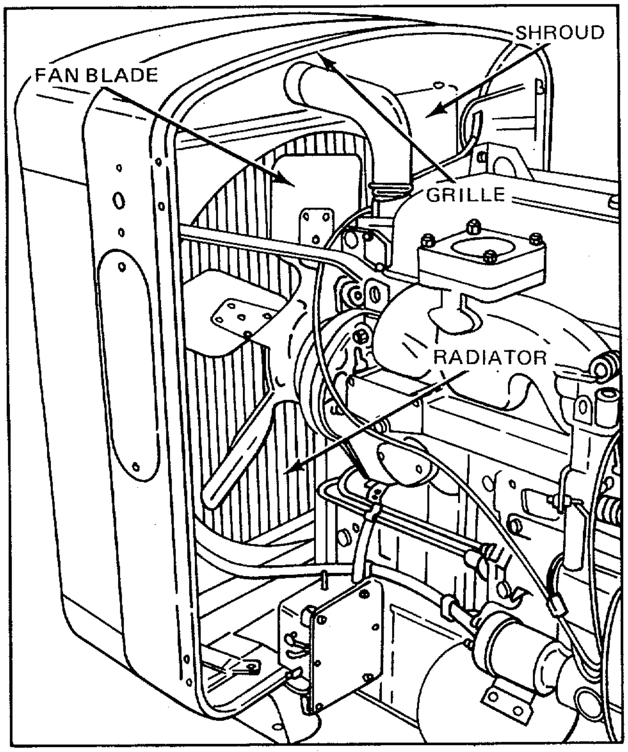


Figure 1. Typical Radiator Mounting (In-Line Engine)

Another cause of overheating is slippage of the fan drive belts which is caused by incorrect belt tension, worn belts or worn fan belt pulley grooves, or the use of fan belts of unequal length when two or more belts are used. The belt tension and condition of the belts should be checked periodically. Refer to *Preventive Maintenance*.

A radiator that has a dirty, obstructed core or is leaking, a leak in the cooling system, or an inoperative thermostat will also cause the engine to overheat. The radiator must be cleaned, the leaks eliminated, and defective thermostats replaced immediately to prevent serious damage from overheating.

The external cleanliness of the radiator should be checked if the engine overheats and no other causes are apparent.

Cleaning Radiator

The radiator should be cleaned whenever the foreign deposits are sufficient to hinder the flow of air or the transfer of heat to the air. In a hot, dusty area, periodic cleaning of the radiator will prevent a decrease in efficiency and add life to the engine.

The fan shroud and grille should be removed, if possible, to facilitate the cleaning of the radiator core.

An air hose with a suitable nozzle is often sufficient to remove loose dust from the radiator core. Occasionally, however, oil may be present requiring the use of a solvent, such as mineral spirits, to loosen the dirt. The use of gasoline, kerosene or fuel oil is NOT recommended as a solvent. A spray gun is an effective means of applying the solvent to the radiator core. Use air to remove the remaining dirt. Repeat this process as many times as necessary, then rinse the radiator with clean water and dry it with air.

WARNING

Provide adequate ventilation of the working area to avoid possible toxic effects of the cleaning spray.

CAUTION

To avoid damage to the radiator fins, do not use high air or water pressure.

Another method of cleaning the radiator is the use of steam or a steam cleaning device, if available. If the foreign deposits are hardened, it may be necessary to apply solvents.

The scale deposit inside the radiator is a result of using hard, high mineral content water in the cooling system. The effect of heat on the minerals in the water causes the formation of scale, or hard coating, on metal surfaces within the radiator, thereby reducing the transfer of heat. Some hard water, instead of forming scale, will produce a silt-like deposit which restricts the flow of water. This must be flushed out at least twice a year -- more often if necessary.

To remove the hardened scale, a direct chemical action is necessary. A flushing compound such as salammoniac, at the specified rate of 1/4 pound per each gallon of radiator capacity, should be added to the coolant water in the form of a dissolved solution while the engine is running. Operate the engine for at least fifteen minutes, then drain and flush the system with clean water.

Other flushing compounds are commercially available and should be procured from a reliable source. Most compounds attack metals and should not remain in the engine for more than a few minutes. A neutralizer should be used in the cooling system immediately after a de-scaling solvent is used.

For extremely hard, stubborn coatings, such as lime scale, it may be necessary to use a stronger solution. The corrosive action of a stronger solution will affect the thin metals of the radiator, thereby reducing its operating life. A complete flushing and rinsing is mandatory and must be accomplished skillfully.

After the solvent and neutralizer have been used and the cooling system is flushed, completely drain the entire system again and fill it with a recommended coolant (refer to Engine Coolant). After filling the cooling system, inspect the radiator and engine for water leaks.

NOTE

When draining or filling, the cooling system must be vented.

COOLANT PRESSURE CONTROL CAP

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap, with a number 7 stamped on its top, is designed to permit a pressure of approximately seven pounds in the system before the valve opens. This pressure raises the boiling point of the cooling liquid and permits somewhat higher engine operating temperatures without loss of any coolant from boiling. To prevent the collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools.

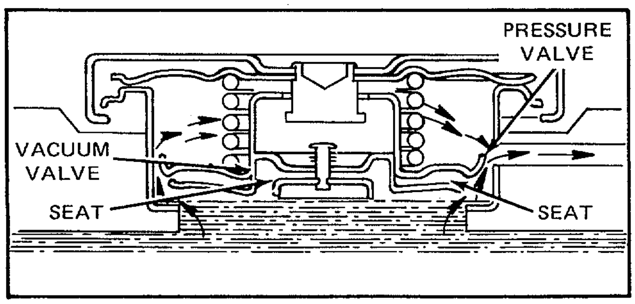


Figure 1. Pressure Control Cap (Pressure Valve Open)

WARNING

Use extreme care while removing the coolant pressure control cap. Remove the cap slowly after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

To ensure against possible damage to the cooling system from either excessive pressure or vacuum, check both valves periodically for proper opening and closing pressures. If the pressure valve does not open between 6.25 psi (43.1 kPa) and 7.5 psi (51.7 kPa) or the vacuum valve is not open at .625 psi (4.3 kPa) (maximum), replace the pressure control cap.

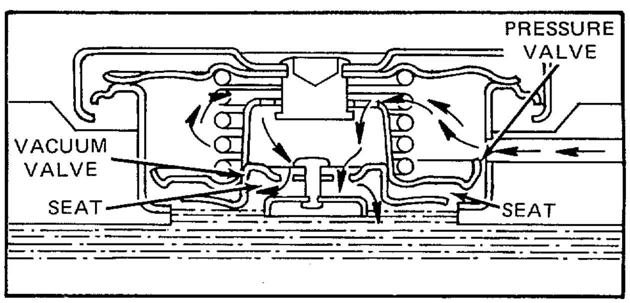


Figure 2. Pressure Control Cap (Vacuum Valve Open)

ENGINE COOLING FAN

The engine cooling fan is driven directly by the crankshaft (Fig. 1). Because of high vibration loads on certain applications, a new 22-inch five balde-type fan with a thicker spider is now being used on the in-line 53 engines as required. This is effective with engine serial number 4D-154007. The former and new fan assemblies are interchangeable on an engine, but only the new fan assembly is serviced.

Effective with engine serial number 4D-68816 new fan hub assemblies are being used on the in-line engines. The new assemblies are similar to the integral cast shaft and bracket design, with tapered roller bearings, currently used on the V-type engines (Fig. 4). A new pulley hub assembly similar to the present hub assembly is now being used on certain four cylinder Series 53 engines to extend operational life under severe dirt conditions. It includes a front ball bearing and a rear roller bearing along with a hubcap (with relief valve), a dust cap, and a grease fitting in the fan pulley hub (Fig. 7).

The belt-driven fan is bolted to a combination fan hub and pulley which turns on a sealed ball bearing assembly (former in-line engines), two tapered roller bearings (present in-line engines) or a front ball bearing and a rear roller bearing (new 4-53 engines). The crankshaft-driven fan is bolted to the crankshaft pulley.

LUBRICATION

The sealed ball bearing, used in the fan hub assembly shown in Fig. 2, is

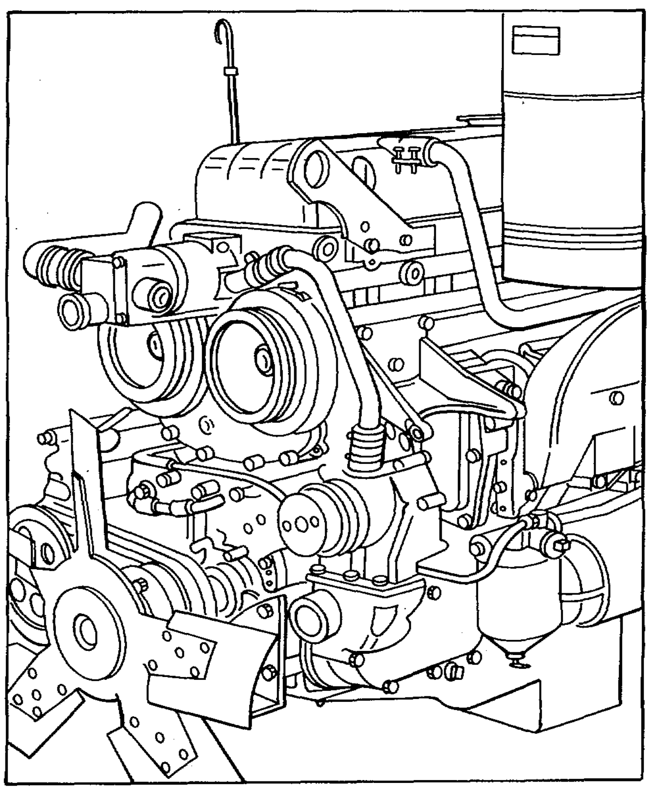


Figure 1. Crankshaft-Driven Fan Mounting (In-Line Engine

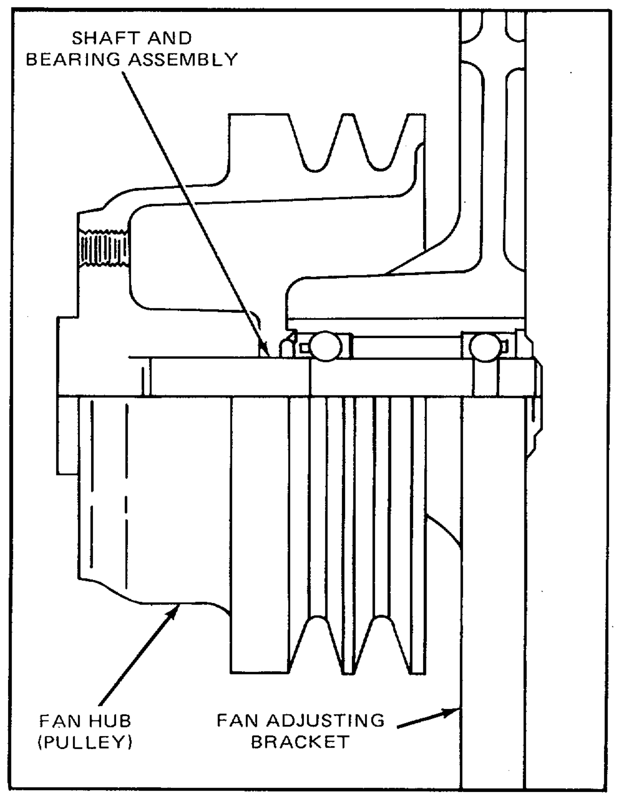


Figure 2. Ball Bearing-Type Fan Hub Assembly

prelubricated and requires no further lubrication.

Fan Belt Adjustment

Adjust the fan belts periodically as outlined in Preventive Maintenance.

Remove Fan, Hub, and Adjusting Bracket

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Bent fan blades reduce the efficiency of the cooling system, may throw the fan out of balance, and are apt to damage the radiator core. Before removing the fan, check the blades for alignment. Do not rotate the fan by pulling on the fan blades.

1. Remove the fan belts and fan guards.

2. Remove the attaching bolts and lockwashers and remove the fan and spacer (if used).

CAUTION

If insufficient clearance exists between the fan and radiator, remove the fan, hub, and adjusting bracket as an assembly.

3. Loosen the fan hub adjusting bracket bolts and remove the drive belts. Then withdraw the bolts and washers and remove the hub and bracket assembly from the engine.

Disassemble Hub and Adjusting Bracket

IN-LINE ENGINES
(Ball Bearing-Type Hub):

1. Refer to Fig. 2 and measure the distance between the rear face of the rim on the pulley and the rear face (machined) of the fan adjusting bracket. Record this measurement for reassembly purposes.

2. Remove the fan hub from the shaft with a puller as shown in Fig. 3.

3. Place the bracket assembly in an arbor press. Then place a suitable sleeve over the shaft and against the outer race of the bearing and press the bearing and shaft assembly from the bracket.

CAUTION

Damage to the bearing will result if force is applied to the shaft.

IN-LINE ENGINES
(Roller Bearing-Type Hub):

1. Refer to Fig. 4 and remove the fan hubcap.

2. Remove the hub bolt and washer.

3. Withdraw the hub and bearing assembly from the shaft. It may be

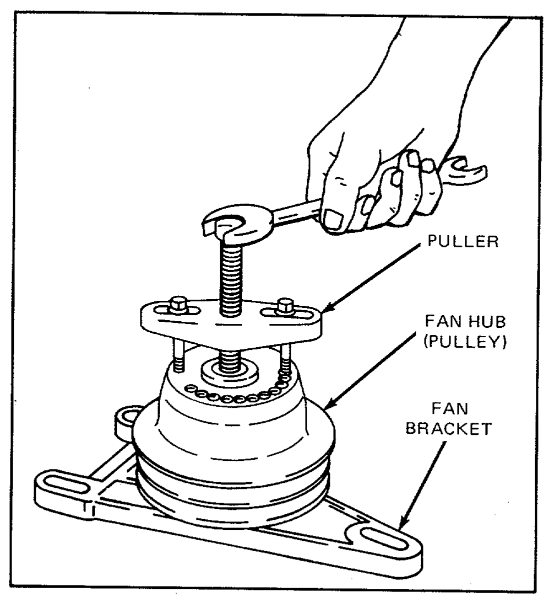


Figure 3. Removing Fan Hub (Pulley)

necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

4. Remove the oil seal and bearing from the fan hub.

5. Remove the bearing spacer, shims and grease retainer.

4-53 ENGINES:

1. Remove the fan hubcap (if a spacer and cap assembly were not used).

2. Remove the hub retaining cotter pin, nut and washer (Fig. 5) or the bolt and special washer (Fig. 6 and 8). Also remove the shims if the former type fan hub assembly illustrated in Fig. 6 is used.

3. Withdraw the hub and bearing assembly from the shaft. It may be necessary to tap the end of the shaft with a soft hammer to loosen the hub assembly.

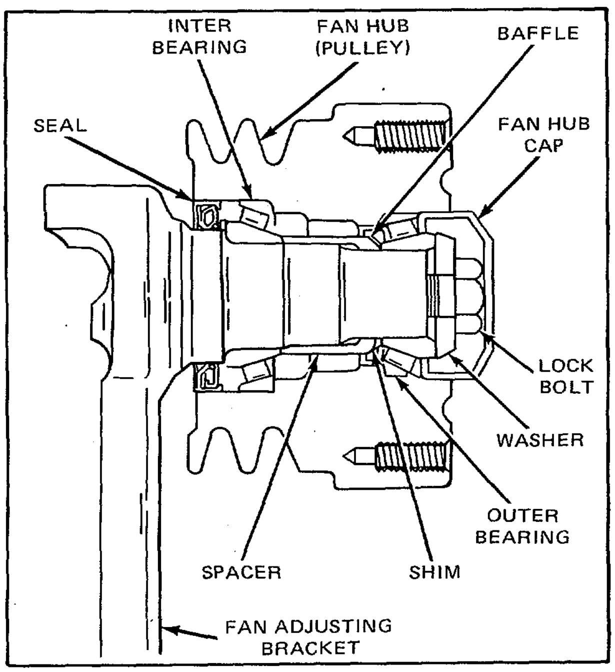


Figure 4. Roller Bearing-Type Fan Hub Assembly (In-Line Engine)

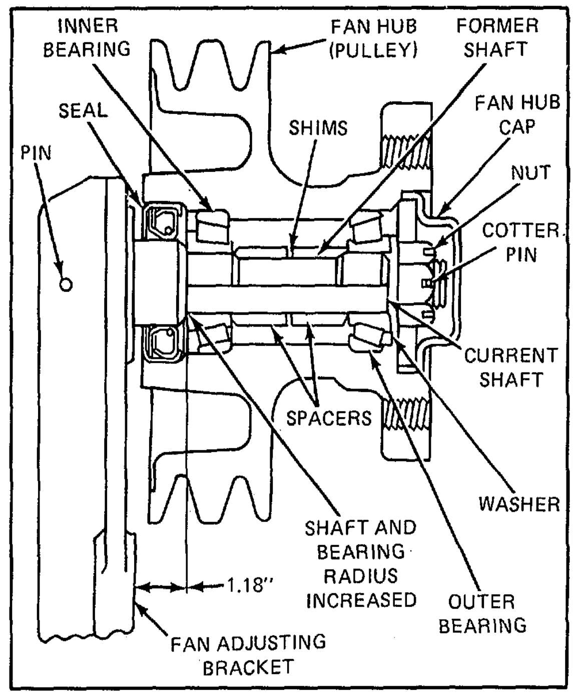


Figure 5. Shaft-Type Fan Hub Assembly

4. Remove the seal and bearings from the fan hub.

5. Remove the bearing spacer (Fig. 6 and 7) and shims (if the current-type hub assembly is used).

INSPECTION

Clean the fan and related parts with clean fuel oil and dry them with compressed air.

CAUTION

Do not wash the permanently sealed bearing which is used in the inline engine roller bearing hub assembly. Wipe the bearing and shaft assembly with a clean, lintless cloth.

Hold the inner race (shaft of sealed ball bearing assembly) and revolve the outer race of the bearing slowly by hand. If rough or tight spots are detected, replace the bearing.

The current fan shaft rear bearing inner race should be inspected for any measurable wear. Replace the inner race if the outer diameter is less than 1.7299 inches.

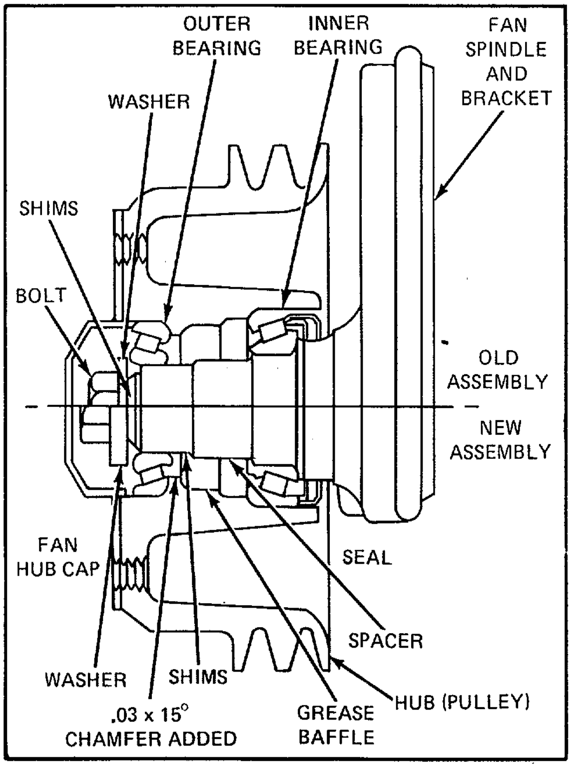


Figure 6. Spindle-Type Fan Hub Assembly

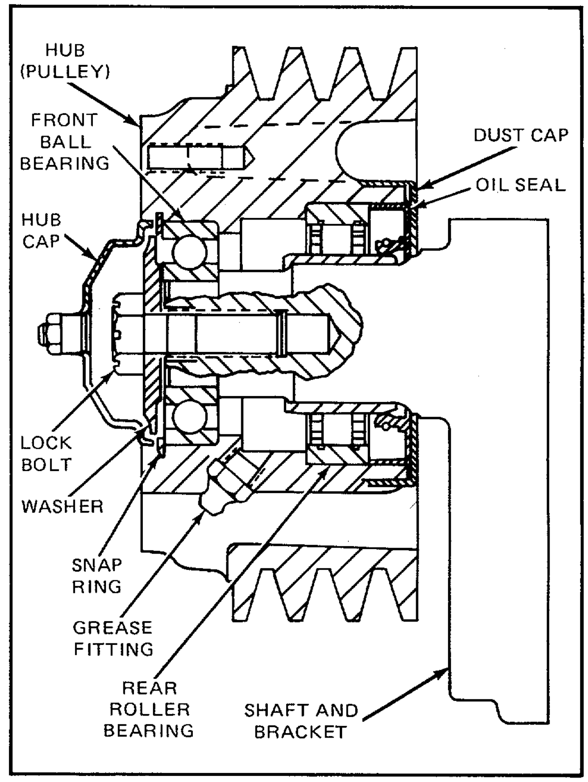


Figure 7. Shaft-Type Fan Hub Assembly

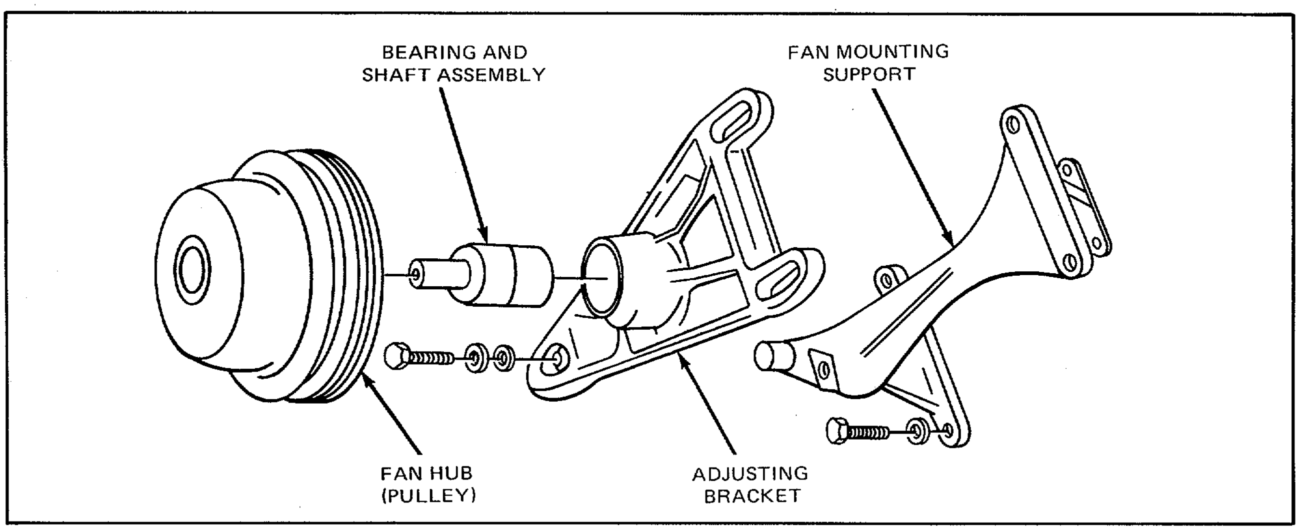


Figure 8. Typical Fan Hub and Adjusting Bracket Details and Relative Location of Parts (In-Line Engine)

NOTE

The inner and outer races are only serviced as a rear roller bearing assembly.

When installing the rear bearing inner race, press it on the shaft and position it 1.35 to 1.37 inches from the end of the shaft.

Check the fan blades for cracks. Replace the fan if the blades are badly bent, since straightening may weaken the blades, particularly in the hub area.

Remove any rust or rough spots in the grooves of the fan pulley and crankshaft pulley. If the grooves are damaged or severely worn, replace the pulleys.

New 0.500 inch thick and 0.800 inch thick fan hub spacers and a new fan hubcap replace the former spacer and cap assemblies to provide spacers compatible with the six bolthole mounting fan hub assemblies. The spacers (individually or in combination) also provide a means for setting the different clearances between the back of the fan blades and front groove of the crank-shaft pulley.

The spacers have a flange on one side that serves as a pilot for the fan as well as a spacer pilot for the second spacer when two or more spacers are used together.

EXAMPLE

A former 1.800-inch-thick spacer and cap assembly have been replaced by two 0.500-inch-thick spacers, one 0.800-inch-thick spacer, and the new fan hubcap.

When replacing the former fan hub spacer, be sure and include the new cap.

The fan hub assembly illustrated in Fig. 5 has been revised. The revisions consist of an increase in the bearing inner race and shaft bearing radii, a hardened hub-retaining nut and washer, and the addition of spacers and shims on the shaft between the bearings. This type fan hub assembly should be rebuilt with the current parts, especially where the former undercut shaft is used. The current spacers and shims cannot be used with the former shaft.

To replace the shaft, remove the groove pin and press the shaft from the adjusting bracket. Press the new shaft in the bracket to the dimension shown in Fig. 5. Then drill the shaft, using the hole in the bracket as a guide, and install a groove pin.

The spindle-type fan hub assembly illustrated in Fig. 6 has also been revised. A bearing spacer has been added and a new outer bearing, which provides a closer fit on the shaft, replaces the old. A baffle has also been added to retain the grease and assure lubrication at the outer bearing. To facilitate installation of the grease baffle, a 0.030 inch by 15° chamfer has been added to the bore in the pulley.

The tapped hole in the end of the shaft has been counterbored and increased in depth from 1.000 inch to 1.260 inches. A longer hub-retaining bolt and a 0.320-inch-thick washer replaces the former bolt and 1/8-inch-thick washer.

New shims, assembled between the bearing spacer and the inner race of the outer bearing, provide .001 inch to .006 inch end play. The former shims, which were assembled between the hub-retaining washer and the end of the shaft, provide 0.002 inch to 0.004 inch end play.

When service is required on the spindle-type shaft, it should be rebuilt with the new components.

Fan hubs equipped with roller bearings (except the sealed type in Fig. 2) may be modified by adding a grease fitting (refer to Cooling System).

Assemble Rub and Adjusting Bracket

IN-LINE ENGINES

(Ball Bearing-Type Hub):

Refer to Fig. 2 and assemble the fan hub and adjusting bracket as follows:

1. Press the shaft and bearing assembly into the adjusting bracket by applying pressure on the outer race of the bearing, using a suitable sleeve, until the bearing is flush with the pulley end of the bracket.

2. Measure the shaft diameter and the pulley bore. It is important that a 0.001 inch -0.002 inch press fit be maintained. Then support the bearing end of the shaft and press the fan hub (pulley) on the shaft to the original dimensions taken during disassembly. This will assure proper alignment and clearance of the parts.

The shaft and bearing assembly are permanently sealed and require no lubrication.

IN-LINE ENGINES

(Roller Bearing-Type Hub):

Assemble the fan hub and spindle shown in Fig. 5 as follows:

1. Apply Texaco Premium RB grease or an equivalent Lithium base multipurpose grease to the rollers of both bearings before installing them in the fan hub (pulley).

2. Install the inner bearing with the protruding face of the inner race facing outward from the hub.

3. Install a new seal with the felt-side flush with the outer edge of the hub.

4. Place the hub over the spindle and install the bearing spacer.

5. Pack the cavity approximately 1/4 full with grease and install the grease baffle.

6. Place the shims against the bearing spacer. Then install the outer bearing with the protruding face of the inner race facing outward from the hub.

7. Place the retaining washer with the breakout side toward the bearing. Install and tighten the bolt to 83-93 lb ft (113-126 Nm) torque while rotating the pulley.

8. Check the end play in the assembly with the spindle (shaft) in a horizontal position. The end play must be within 0.001 inch to 0.006 inch. If necessary, remove the bolt, washer, and outer bearing and adjust the number and thickness of shims to obtain the required end-play. Shims are available in 0.015, 0.020 and 0.025 inch thickness. Then reassemble the fan hub and check the end play.

9. Fill a new fan hubcap 3/4 full of grease and install it in the end of the fan hub (pulley).

4-53 ENGINES

(Front Ball and Rear Roller Bearing):

Assemble the new pulley hub as follows:

1. Apply Texaco Premium RB grease or an equivalent Lithium base multipurpose grease to the front ball bearings and the rollers of the rear bearing, before installing them in the pulley hub.

CAUTION

Do not over grease

2. Install the front ball bearing against the shoulder counterbore in the pulley hub. Then install the snap-ring in the pulley hub.

3. Install the rear roller bearing outer ring and roller assembly against the shoulder in the counterbore of the pulley hub.

4. Install a new oil seal with rubber side flush with the outer edge of the hub.

5. Install the dust cap (if used) over the oil seal in the hub.

6. Place the shaft and bracket on wood block setting on the bed of an arbor press. Then press the rear bearing inner ring or race onto the fan shaft.

7. Pack the cavity 3/4 full with Texaco Premium RB grease.

8. Install the partially assembled fan hub over the rear bearing inner ring on the shaft and against the shoulder on the pulley hub shaft.

9. Secure the hub with the washer and 1/2-20 lock bolt. Tighten the bolt to 83-93 lb ft (113-126 Nm) torque while rotating the pulley hub.

10. Fill a new fan hubcap 3/4 full of grease and install it in the end of the pulley hub.

Install Fan, Hub, and Adjusting Bracket

1. Attach the fan hub and adjusting bracket assembly to the support bracket on the engine with bolts, lockwashers, and plain washers. Do not tighten the bolts until the fan belts are installed.

2. Install the drive belts and adjust the belt tension as outlined in Preventive Maintenance. If used, install the adjusting bracket, bolt, and plain washer.

3. Install the fan (and fan spacer and cap, if used) on the hub and secure it with the 5/16-18 bolts and lockwashers (Cooling System).

COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass-type unit with a replaceable canister-type element (Fig. 1), a spin-on-type element (Fig. 2) or a clamp-on-type element (Fig. 3).

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity, and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat. Figure 1. Coolant Filter and Conditioner (Canister-Type)

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system (refer to Coolant Specifications). The other components of the element perform the function of cleaning and preparing the cooling passages while the corrosion inhibitors protect them.

Filter Installation

If a coolant filter and conditioner is to be installed on an engine which has been in service, drain and flush the cooling system prior to installation of the filter. Figure 2. Coolant Filter and Conditioner (Spin-On-Type)

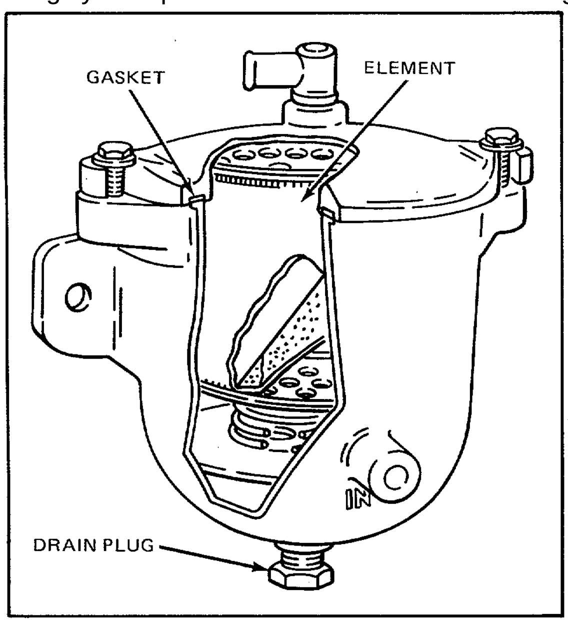


Figure 1. Coolant Filter and Conditioner (Canister Type)

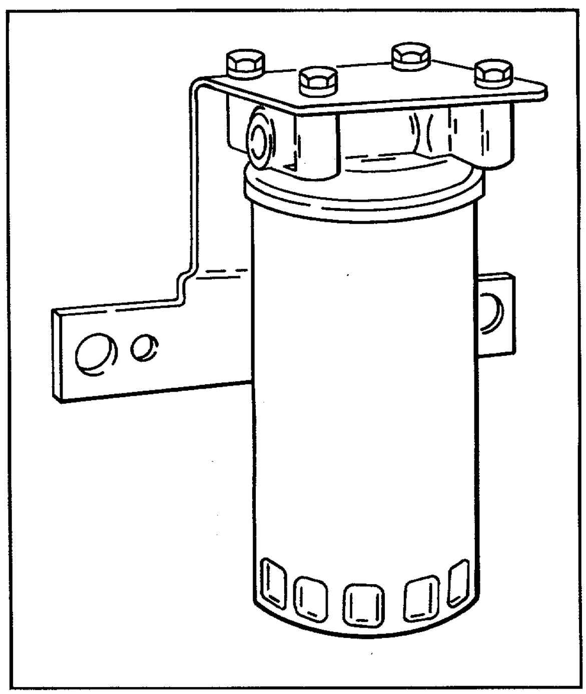


Figure 2. Coolant Filter and Conditioner (Spin-On-Type)

Filter Maintenance

Replace the chemically-activated element, following the manufacturer's recommended change periods (refer to Preventive Maintenance). The lower corrosion resistor plate (if used) must be buffed each time (discard the plate if excessive metal loss or pitting is evident) to ensure effective protection of the cooling system.

If the filter is installed on an engine which has previously been in service, it may be necessary to change the filter element two or three times at intervals of approximately 200 hours or 6,000 miles, or less, to clean-up accumulations of scale and rust in the cooling system. It is advisable to drain and flush the system during these initial change intervals. Makeup water up to approximately 40% of the total capacity of the cooling system may safely be added before a filter element change is required.

If it is necessary for any reason to drain the cooling system before an element change, the treated water should be saved and reused. If the treated water is discarded, a new filter element must be installed since the protective agents in the used filter will have been partially consumed in treating the discarded water.

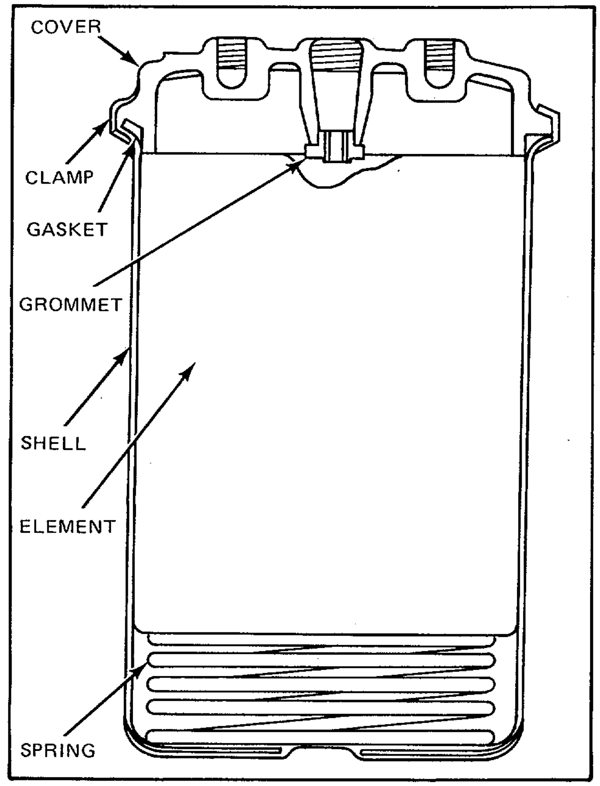


Figure 3. Coolant Filter and Conditioner (Clamp-On-Type)

Service

The coolant filter may be grounded at the option of the user.

The current coolant filter includes a nonchromate type element. This element can be used in place of either of the former filter elements (permanent-type antifreeze or plain water-type) and thus provides year-round cooling system protection. The current and the former filter elements are completely interchangeable in the former filter can.

Replace the element and service the filter and conditioner as follows:

1. Close the filter inlet and outlet shutoff valves. If shutoff valves are not provided, vise grip pliers can be used to clamp each hose closed during the filter change. Use caution to avoid damaging the hoses with the vise grip pliers.

2. Canister-Type Element:

   a. Remove the drain plug in the bottom of the filter body and let drain.

   b. Remove the filter cover-to filter body bolts.

   c. Remove and discard the element.

   d. Remove and discard the corrosion resistor plates.

e. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

f. Replace the drain plug in the bottom of the filter.

g. Insert the new element.

h. Use a new filter cover gasket and install the filter cover and tighten the bolts evenly.

3. Spin-On-Type Element:

a. Remove and discard the element.

b. Clean the gasket seal on the filter cover.

c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

d . Apply clean engine oil to the filter element gasket and install the new element. A 1/2 to 3/4 turn after gasket contact assures a positive leak proof seal.

4. Clamp-On-Type Element:

a. Remove the retaining clamp.

b. Remove and discard the element.

c. Remove the sludge and sediment and wash the filter body. Dry it thoroughly with compressed air.

d. Insert the new element.

e. Secure the filter body in place with the clamp.

5. Open the inlet and outlet lines by opening the shutoff valves or removing the vise grip pliers clamps.

6. Operate the engine and check for leaks. The top of the filter and outlet line should feel warm to the touch with the rise in coolant temperature. If not, disconnect the filter outlet line at the end opposite the filter connection to bleed the air from the system and reconnect the line. Use caution to minimize coolant loss.

COOLANT SYSTEM

SHOP NOTES - SPECIFICATIONS - SERVICE TOOLS

SHOP NOTES

FAN HUB SPACER

The new fan hub spacers are similar to the former spacers except for the flange pilot radius and the width of the spacers (Fig. 1). The flange on the spacer serves as a pilot for the fan, as well as a pilot for the second spacer when two or more spacers are used together.

The former and new spacers are interchangeable on a former fan pulley hub assembly and only the new spacers are serviced. The former 0.800-inch thick spacer must not be used with the current shaft-type fan pulley hub assemblies, unless it is reworked (see Service).

Use of the former thick spacer will crush the fan hubcap causing the drive to bind.

SERVICE: The former 0.800-inch thick spacer can be reworked into the new 0.800-inch thick spacer by removing material at the radius (Fig. 1). A

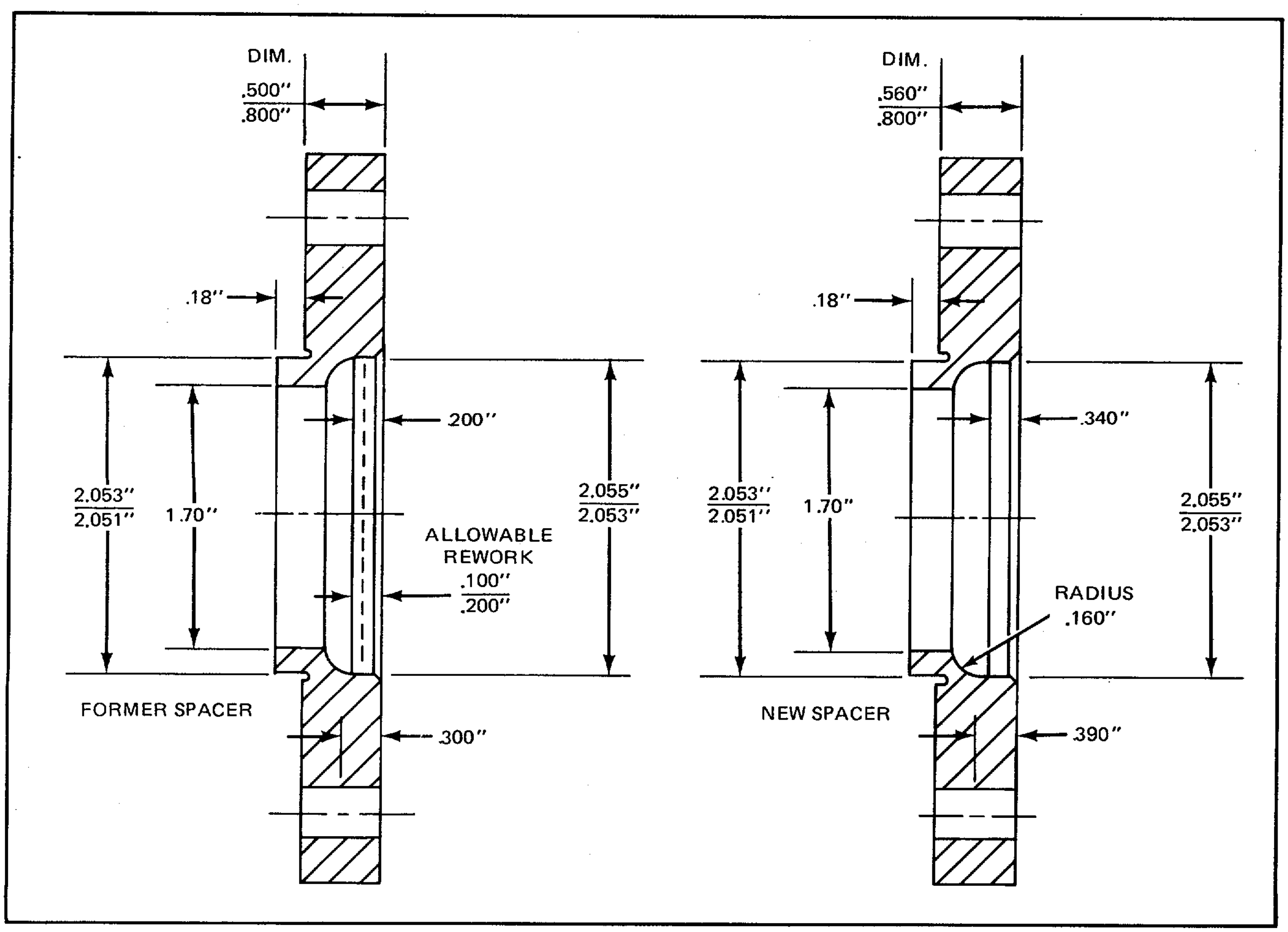


Figure 1. Former and New Spacers

reworked spacer should be mated with the fan hub assembly. If a former thin spacer (0.500-inch thick) is used in conjunction with the reworked thick spacer, it should be positioned against the fan.

NOTE

The 0.500-inch thick spacer cannot be reworked into the new O.560-inch thick spacer.

A grease fitting may be added to former fan hub assemblies used on vehicle engines to permit periodic lubrication of the bearings.

Rework the fan hub as follows:

1. Refer to *Engine Cooling Fan* and disassemble the fan hub assembly, and clean the parts thoroughly.

2. Drill and tap the fan hub, at the location shown in Fig. 1, to accept a 1/8 PTF x 11/16 inch threaded lubricator fitting. Clean the hub to remove any metal chips.

3. Refer to Engine Cooling Fan and reassemble the fan hub. Discard the

4. Install a new fan hubcap which is threaded for a relief valve (Fig. 1).

5. Install a grease fitting in the fan hub and a relief valve in the fan hubcap. *Refer to Preventive Maintenance* for the maintenance schedule.

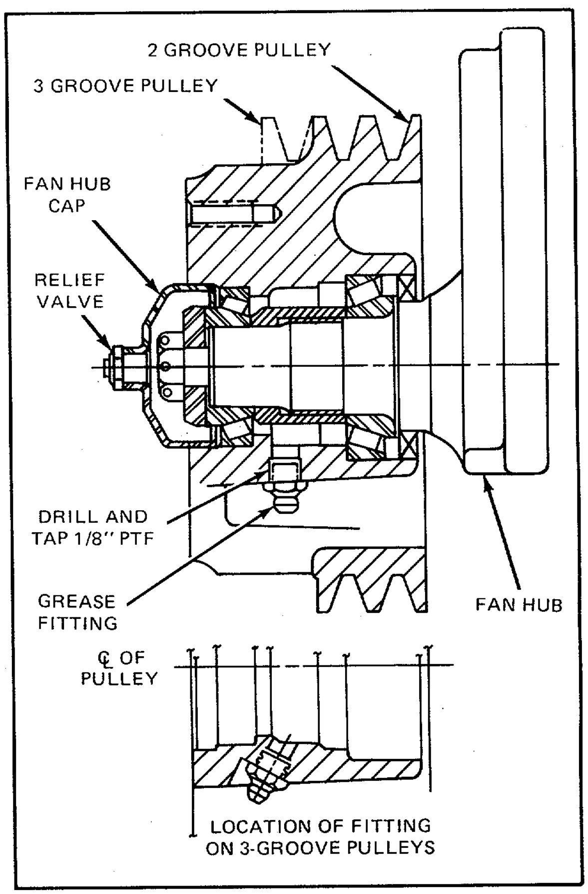


Figure 2 . Location of Fan Hub Grease Fitting and Relief Valve

SPECIFICATIONS

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb ft)	260M BOLTS TORQUE (Nm)	THREAD SIZE	280M OR BETTER TORQUE (lb ft)	280M OR BETTER TORQUE (Nm)
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	810	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

BOLT IDENTIFICATION CHART

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designation	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM-260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM-275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	BM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Water pump cover bolt	5/16-18	6-7	8.1-9.5

SERVICE TOOLS

TOOL NAME	TOOL NO.
Handle	J 7092-2
Installer	J 22091
Puller	J 24420
Remover and installer	J 1930
Water pump impeller remover set	J 22488

EXHAUST SYSTEM

Fan and radiator-cooled engines are equipped with an air-cooled exhaust manifold.

The outlet flange may be located at the end or at the mid-section of the exhaust manifold, depending upon the installation requirements. A flexible exhaust connection or a muffler may be attached to the outlet flange. The exhaust manifold is attached to studs located between the exhaust ports and the outer side of the two end ports in the cylinder head. Special washers and nuts secure the manifold to the cylinder head.

EXHAUST MANIFOLD

Two types of exhaust manifolds are used. One type has an outlet to accommodate a square exhaust outlet flange (Fig. 1) and the other has a circular outlet which is connected to the exhaust pipe with a Marmon-type clamp (Fig. 2). Current manifolds, flanges (square), and flange gaskets have SAE standard dimensions.

On engines equipped with a mechanical automatic shutdown system, the exhaust manifold is provided with two 5/16-18 tapped bolt holes and a 7/8 inch drilled hole to permit installation of the temperature shutdown valve adaptor and plug assembly.

Remove Exhaust Manifold

1. Disconnect the exhaust pipe or muffler from the exhaust manifold flange.

2. If the engine is equipped with a mechanical automatic shutdown system, remove the two bolts and lockwashers and withdraw the shutdown valve adaptor and plug assembly from the exhaust manifold.

3. Loosen, but do not remove, one of the center exhaust manifold nuts. Remove the other nuts and washers.

4. Support the manifold and remove the center nut and washer.

5. Remove the manifold and gasket from the cylinder head.

Inspection

Remove any loose scale and carbon that may have accumulated on the internal walls of the exhaust manifold. Clean the manifold and check for cracks, especially in the holding lug areas.

Clean all traces of gasket material from the cylinder head.

Examine the exhaust manifold studs. Replace damaged studs. Apply sealant

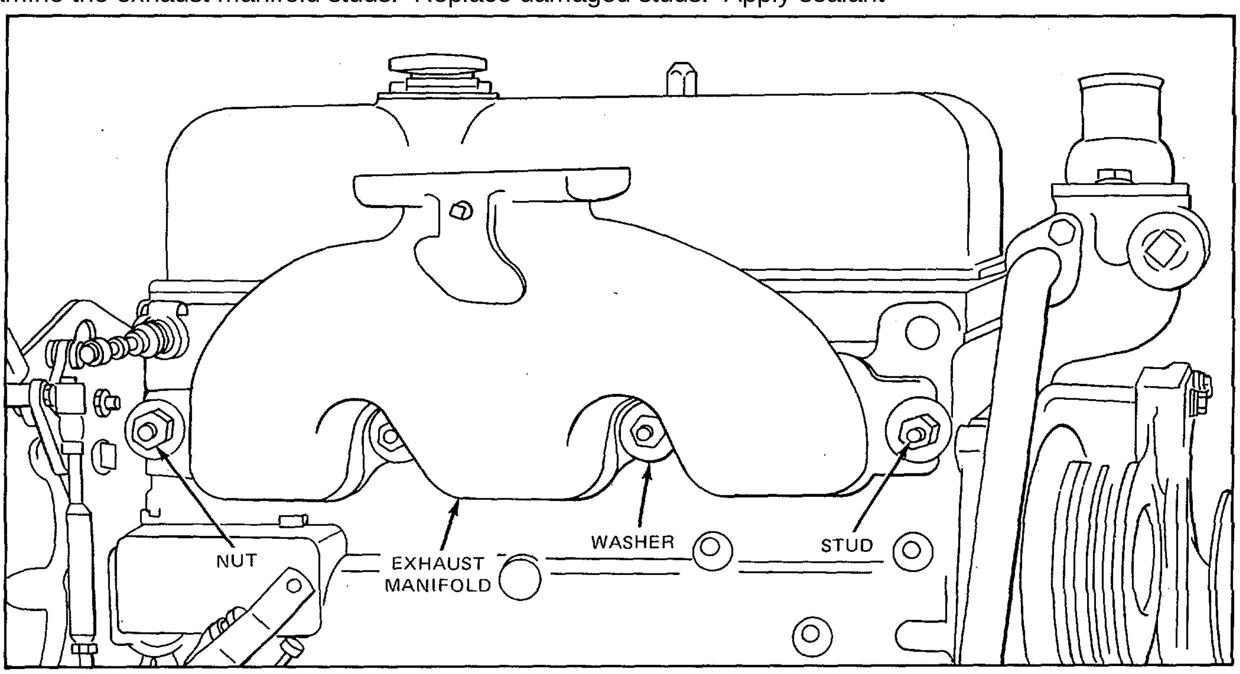


Figure 1 . Typical Air-Cooled Exhaust Manifold (Square Flange) Mounting

to the threads and drive new studs to 25-40 lb ft torque (1.40 to 1.50 inch height).

Install Exhaust Manifold

1. Place a new gasket over the studs and against the cylinder head.

2. Position the exhaust manifold over the studs and hold it against the cylinder head.

3. Install the washers and nuts on the studs. If beveled (dished) washers are used, position them so that the crown side faces the nut. On some engines, crabs are used in place of washers at the end positions (Fig. 2). Beginning with one of the center stud nuts and working alternately toward each end of the manifold, tighten the nuts to 30-35 lb ft torque.

4. If the engine is equipped with a mechanical automatic shutdown assembly, install the shutdown valve adaptor and plug assembly in the exhaust manifold and secure it with two bolts and lockwashers.

5. Connect the exhaust pipe or muffler to the exhaust manifold flange.

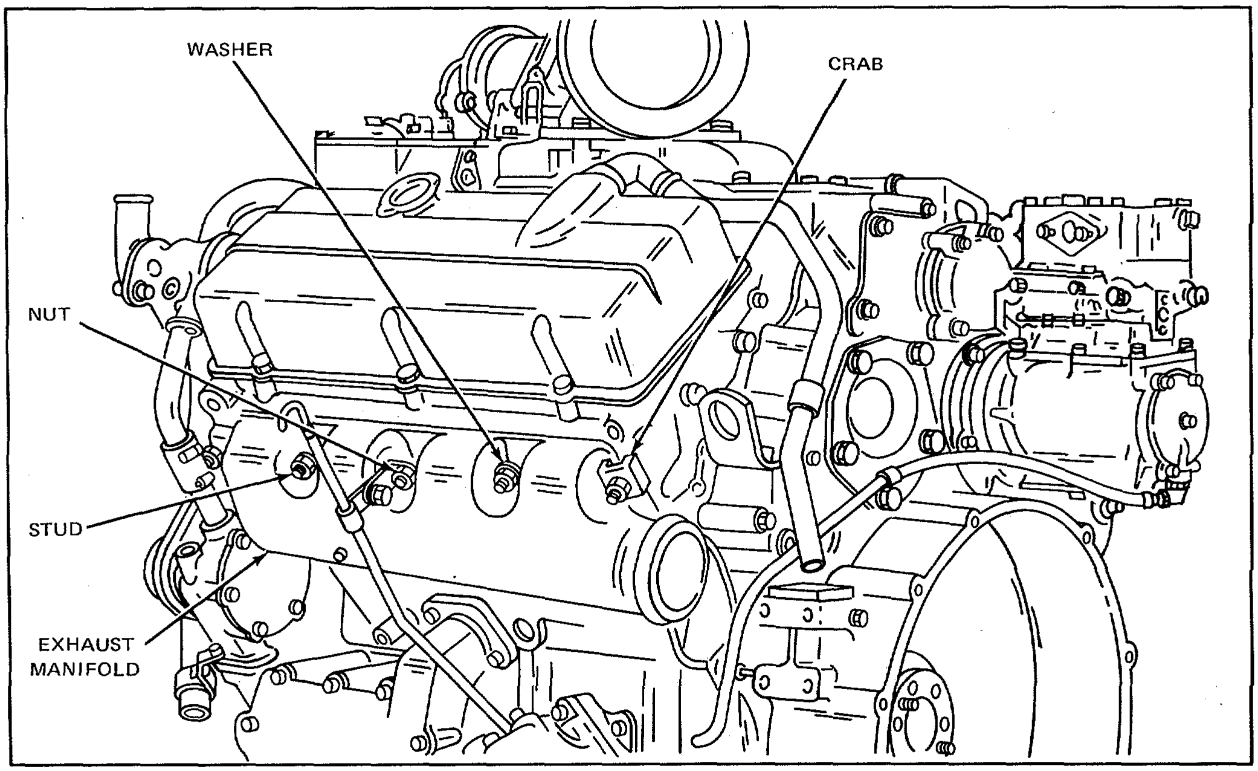


Figure 2 . Exhaust Manifold with Marmon Flange

ELECTRICAL SYSTEM

A typical engine electrical system generally consists of a starting motor, a battery-charging generator (alternator), a transistor combination voltage regulator, current regulator and cutout relay to protect the electrical system, a storage battery, and the necessary wiring.

Additional equipment such as an engine protective system may also be included.

BATTERY-CHARGING ALTERNATOR

The battery-charging circuit consists of an alternator, regulator, battery, (storage Battery) and the wiring. The battery-charging alternator (Fig. 1) is introduced into the electrical system to provide a source of electrical current for maintaining the storage battery in a charged condition and to supply sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

HINGE-MOUNTED ALTERNATOR (Belt-driven)

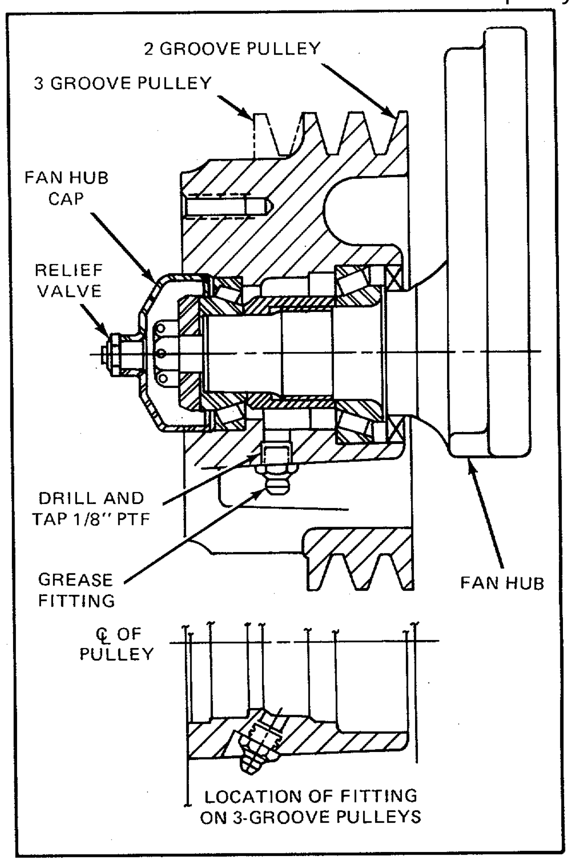
The hinge-mounted alternating current self-rectifying alternator is belt driven. The alternator drive pulley is keyed to a shaft which is coupled to the blower drive gear.

An adequate alternator drive ratio is necessary for an engine equipped with extra electrical accessories and one that has to operate for extended periods at idle speeds. Diodes, built into the slip ring end frame, rectify the three phase ac voltage to provide dc voltage at the battery terminal of the alternator, thereby eliminating the need for an external rectifier alternator is also available in various sizes and types, depending upon the specific application.

The SI series alternators have replaced the DN series alternator. With the new alternators, the need for a separately mounted voltage regulator is eliminated.

NOTE

Effective with November, 1979built engines, the 10SI alternators were converted to metric dimensions, such as the attaching bolts, nuts, and lockwashers. Also, hole sizes of some mounting parts will be changed to accommodate the new metric fasteners. The output terminal (BAT) thread will be changed from a 12-24 to a M16XI thread.



The Figure 1. Typical Hinge-Mounted Alternator (In-Line 53)

The access hole permitting the external adjustment of the voltage regulator has been eliminated on current alternators. To adjust the voltage setting on the current alternators, remove the rectifier end plate. The voltage regulator circuit board. Refer to the pertinent Delco Service Bulletin for complete adjustment procedure.

Alternator Maintenance

1. Maintain the proper drive belt tension. Replace worn or frayed belts. Belts should be replaced as a set when there is more than one belt on the generator or alternator drive.

CAUTION

When installing or adjusting the drive belt, be sure the bolt at the pivot point is properly tightened, as well as the bolt in the adjusting slot.

2. Alternator bearings are permanently lubricated. There are no external oiler fittings.

Remove Alternator

1. Disconnect the cables at the battery supply. If the generator or alternator has a separately mounted regulator and field relay, disconnect all other leads from the alternator and tag each one to ensure correct reinstallation.

2. Loosen the mounting bolts and the adjusting strap bolt. Then remove the drive belts.

3. While supporting the alternator, remove the adjusting-strap bolt and washers. Then remove the mounting bolts, washers, and nuts. Remove the alternator carefully and protect it from costly physical damage.

4. Remove the pulley assembly if the generator or alternator is to be replaced.

Alternator Service

Repairs and overhaul work on alternators should be referred to an authorized repair station of the manufacturer of this equipment. Replacement parts for alternators should be ordered through the equipment manufacturer's outlets. For alternators manufactured by Delco-Remy Division, repair service and parts are available through AC Delco branches and repair stations.

Install Alternator

1. Install the drive pulley, if it was removed. Tighten the pulley retaining nut to 50-60 lb ft (68-81 Nm) torque (Fig. 2).

NOTE

If the pulley was not removed, check the retaining nut for proper torque.

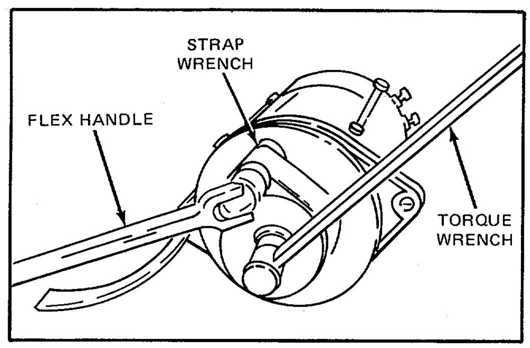


Figure 2. Tighten Alternator Pulley Retaining Nut

2. Position the alternator on the mounting brackets and start the bolts, with washers in place, through the boltholes in the end frames. If nuts are used, insert the bolts through the boltholes in the mounting bracket and end frame. Make sure that the washers and nuts are in their proper locations.

3. Align the threaded hole in the adjusting lug of the drive end frame with the slot in the adjusting strap. Start the bolt, with the washers, through the slot of the adjusting strap and into the threaded hole in the end frame.

4. Place the drive belts in the grooves of the pulleys.

5. Adjust the belt tension as outlined in Preventive Maintenance. Tighten all of the bolts after the belt tightening is completed.

6. Attach the wires and cables. Be sure that each one is correctly installed in accordance with its previous location on the generator or alternator. Keep all connections clean and tight.

ALTERNATOR PRECAUTIONS

Precautions must be taken when working on or around alternators. The diodes and transistors in the alternator circuit are very sensitive and can be easily destroyed.

Avoid grounding or shorting the output wires or the field wires between the alternator and the regulator. Never run an alternator on an open circuit.

Grounding an alternator's output wire or terminals, which are always "hot" regardless of whether or not the engine is running or accidental reversing of the battery polarity will destroy the diodes. Grounding the field circuit will also result in the destruction of the diodes. Some voltage regulators provide protection against some of these circumstances. However, it is recommended that extreme caution be used.

Accidentally reversing the battery connections must be avoided.

Never disconnect the battery while an alternator is in operation. Disconnecting the battery will result in damage to the diodes due to the momentary high voltage and current generated by the rapid collapse of the magnetic field surrounding the field windings.

If a booster battery is to be used, the batteries must be connected correctly (negative to negative and positive to positive).

Never use a fast charger with the battery connected or as a booster for battery output.

Never attempt to polarize the alternator.

The alternator diodes are also sensitive to heat and care must be exercised to prevent damage to them from soldering irons, etc.

If faulty operation of an alternator occurs on an engine equipped with an insulated starting motor, check to be sure that a ground strap is present and is correctly installed.

REGULATOR
AC CHARGING CIRCUIT

The alternating-current generator regulator is similar in outward appearance to the regulator used with the dc generator. The dc and ac regulators are NOT interchangeable.

The internal wiring circuits of all standard ac generator regulators are similar, but the internal connections vary somewhat according to the method used to control the circuit breaker relay.

There are two and three unit standard ac generator regulators; the two-unit regulators have a circuit breaker relay controlled by a relay rectifier or by an oil-pressure switch and the three unit regulators have a circuit breaker relay controlled by a built-in control relay.

The generator field circuit is insulated in the generator and grounded in the regulator. This type of connection is designated as Circuit A.

CAUTION

Each type of regulator is used with a certain circuit. Do not attempt to interchange regulators.

The two-unit ac generator regulator has a circuit breaker relay and a voltage regulator unit while the three-unit regulator is also equipped with a control relay in addition to the other two units.

CIRCUIT BREAKER RELAY

The circuit breaker relay has a core with the winding made up of many turns of fine wire. This core and winding are assembled into a frame. A flat steel armature is attached to the frame by a hinge and is centered above the core. Two contact points, supported by two flat springs on the armature, are located above two stationary contact points. The upper and lower contact points are held apart by the tension of a flat spring riveted to the top side of the armature.

Operation

When the dc voltage reaches the value for which the circuit breaker relay is adjusted, the magnetism induced in the core by current flow in the winding is sufficient to overcome the armature spring tension and the relay points close. Closing of the contact points connects the dc side of the power rectifier to the battery so that current will flow to the battery whenever the generator is driven at sufficient speed.

The relay contact points remain closed as long as the dc voltage is enough to hold the relay armature against the core. They open when the voltage decreases to a value at which the magnetic pull of the core can no longer overcome the armature spring tension.

VOLTAGE REGULATOR

The voltage regulator unit has a core with a single shunt winding. This winding also consists of fine wire and is connected across the dc side of the power rectifier. The assembly and parts are similar to the circuit breaker relay. The matching upper contact point is supported by a detachable contact support insulated from the frame.

Operation

If the voltage regulator unit is not operating, the generator field circuit is completed to ground through the contact points which are held closed by the tension of a spiral spring acting on the armature.

When the dc voltage of the ac - dc system reaches the value for which the voltage regulator is adjusted, the magnetic field produced by the shunt winding overcomes the armature spring tension and pulls the armature down, causing the contact points to separate. When the contact points separate, resistance is introduced into the field circuit. The resistance decreases the field current causing a corresponding decrease in generator voltage and magnetic pull on the regulator armature. This allows the armature spring tension to reclose the contact points. When the voltage again reaches the value for which the voltage regulator is adjusted, this cycle repeats and continues to repeat many times a second, thus limiting the voltage to the value for which the regulator is set.

With the voltage limited in this manner, the generator supplies varying amounts of current to meet the various states of battery charge and electrical load.

Voltage regulators are compensated for variations in temperature by means of a bimetal thermostatic hinge on the armature. The effect of this hinge causes the regulator to adjust at a higher voltage when cold, which partly compensates for the fact that a high voltage is required to charge a cold battery.

CONTROL RELAY

In addition to a circuit breaker and a voltage regulator, the three-unit regulator has a control relay unit. This unit has a core with a single shunt winding connected from the SW terminal of the regulator to ground. The winding and core are assembled into a frame. A flat steel armature supporting the upper one of two relay contacts is attached to the frame by a hinge and is centered above the core. The lower contact point is supported by a detachable contact support insulated from the frame. An armature stop is assembled above the upper contact.

Operation

When the ignition switch is OFF, the contact points are held apart by the tension of a spiral spring acting on the armature. When the ignition switch is turned ON, battery current flows through the control relay winding to ground. The magnetic field produced by the winding overcomes the armature spring tension and pulls the armature down causing the contact points to close. This completes the circuit to ground for the circuit breaker relay winding so that it can operate when the dc voltage from the power rectifier reaches the value for which the circuit breaker relay is adjusted. The control relay contact points remain closed until the ignition switch is turned OFF.

TRANSISTORIZED AND TRANSISTOR REGULATORS

In addition to the standard regulator, there are two other types of regulators being used with the self-rectifying ac generators in the battery-charging circuit. One is a transistorized regulator which contains a vibrating voltage regulator unit and a field relay unit. The other is a transistor regulator which contains no moving parts and is used with a separately mounted field relay.

TRANSISTORIZED REGULATOR

The transistorized regulator (Fig. 1), for use on a negative ground circuit, contains a vibrating voltage regulator unit and a field relay unit. The regulator uses a single transistor and two diodes. The transistor works in conjunction with the conventional voltage unit having a vibrating contact point to limit the generator voltage to a preset value. A field discharge diode reduces arcing at the voltage regulator contacts by dissipating the energy created in the generator field windings when the contacts separate. A suppression diode prevents damage from transient voltages which may appear in the system.

Certain transistorized regulators are equipped with a choke coil to permit the installation of a capacitor between the regulator and the BAT terminal on installations experiencing radio interference. The capacitor suppresses the radio noise and the choke coil acts to prevent oxidation of the voltage regulator contacts. Regulators incorporating the choke coil are identified by a spot of green paint on the regulator base, next to the single mounting bolthole.

CAUTION

A capacitor must not be installed unless the transistorized regulator incorporates the choke coil.

Operation

When the engine starting switch is closed, the field relay winding is energized and causes the contacts to close. Current then flows from the battery through the relay contacts to the regulator F2 terminal. From this point, the current flows through the generator field winding and then through the transistor and voltage contact points to ground.

As the generator speed increases, the increased voltage from the generator BAT terminal is impressed through the field relay contacts across the regulator shunt winding. The magnetism

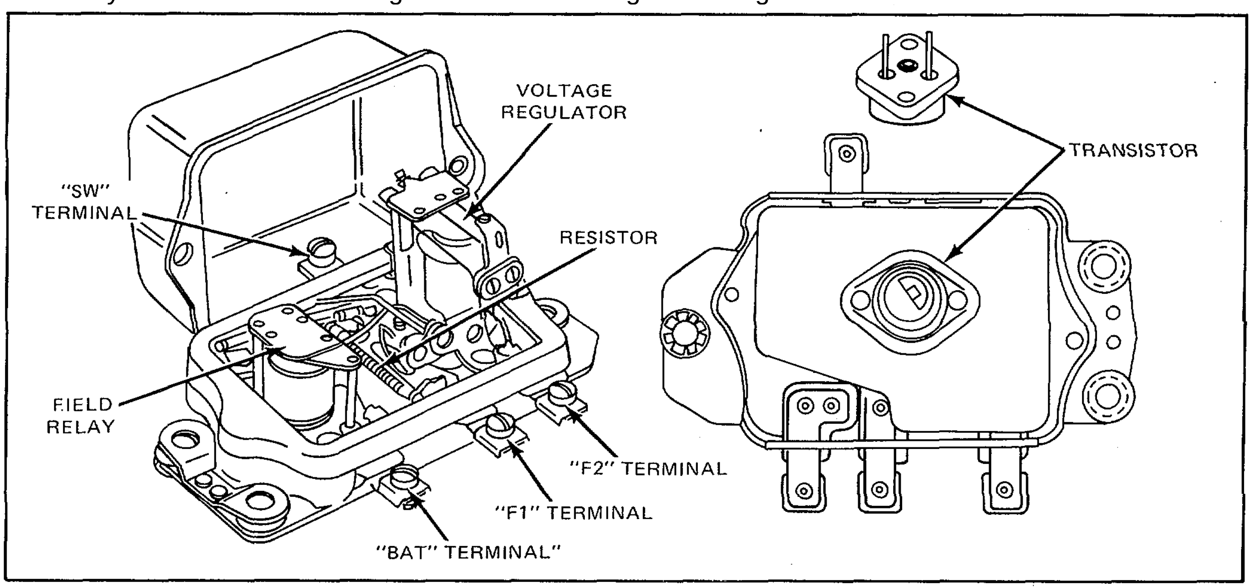


Figure 1 . Transistorized Regulator

created in the winding causes the voltage contacts to open, thus causing the transistor to shutoff the field current. The generator voltage then decreases and the voltage contacts reclose. This cycle repeats many times per second, thereby limiting the generator voltage to the value for which the regulator is set.

The magnetism produced in an accelerator winding, when the voltage contacts are closed, aids the shunt winding in opening the contacts.

When the contacts are open, the absence of the magnetism in the accelerator winding allows the spring to immediately reclose the contacts. This action speeds up the vibration of the contacts.

CAUTION

Do not short across or ground any of the terminals on the regulator or the generator and DO NOT attempt to polarize the generator.

TRANSISTOR REGULATOR

The transistor regulator is composed principally of transistors, diodes, capacitors, and resistors to form a completely static electrical unit containing no moving parts.

The transistor is an electrical device which limits the generator voltage to a preset value by controlling the generator field current. The diodes, capacitors, and resistors act together to aid the transistor in performing this function, which is the only function that the regulator performs in the charging circuit.

The voltage at which the generator operates is determined by the regulator adjustment. Once adjusted, the generator voltage remains almost constant, since the regulator is unaffected by length of service, changes in temperature, or changes in generator output and speed.

A separately mounted field relay connects the regulator POS terminal and the generator field windings to the battery when the engine starting switch is closed.

The voltage regulator illustrated in Fig. 2 is designed for negative ground battery-charging circuits only. It has two exposed terminals. The voltage setting may be adjusted by relocating a screw in the base of the regulator.

The voltage regulator shown in Fig. 3 has shielded plug-in connections and requires a cable and plug assembly to connect the regulator into the battery charging circuit. This type of regulator may be used in negative ground, positive ground, and insulated charging circuits. The voltage setting may be adjusted by removing a plug in the cover and turning a slotted adjusting button inside the regulator.

Operation

When the engine starting switch is closed, the field relay winding is energized, which causes the relay contacts to close.

In the negative ground circuit with the field relay contacts closed and the engine not running, generator field current can be traced from the battery through the relay contacts to the regulator POS terminal. Current then continues through the back-bias diode (D-1) and power transistor (TR-1) to the regulator FLD terminal, and then through the generator field winding to ground, completing the circuit back to the battery.

When the generator begins to operate, ac voltages are induced in the stator windings. These voltages are changed, or rectified, to a dc voltage which appears at the output, or BAT, terminal

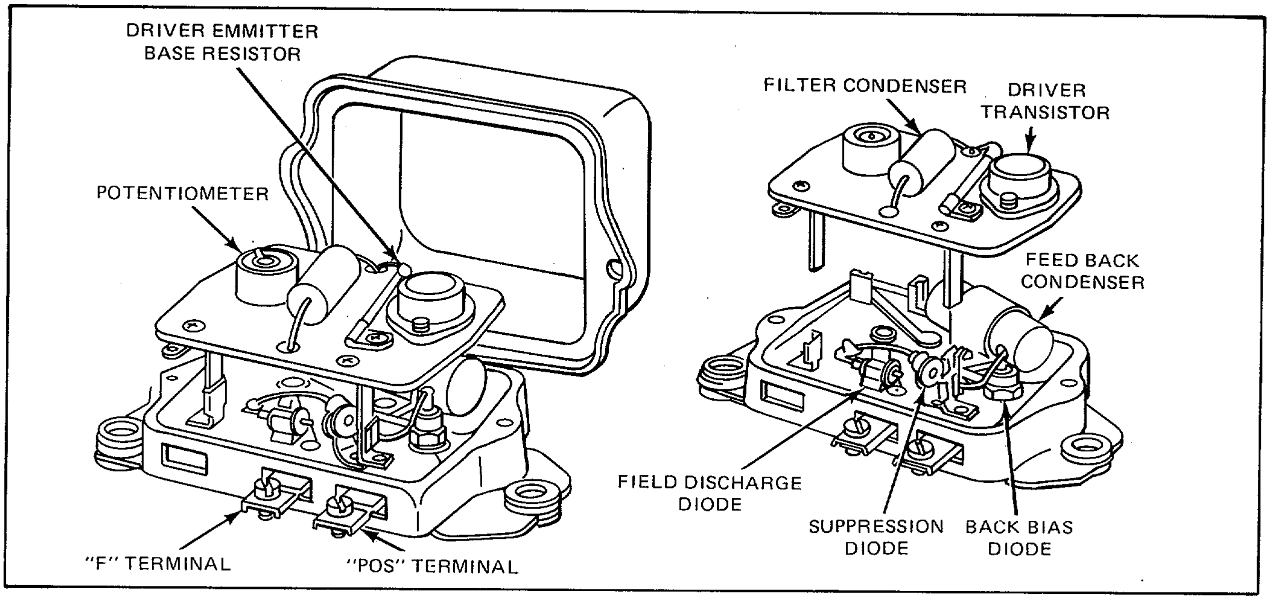


Figure 2. Transistor Regulator (Negative Ground Circuits Only)

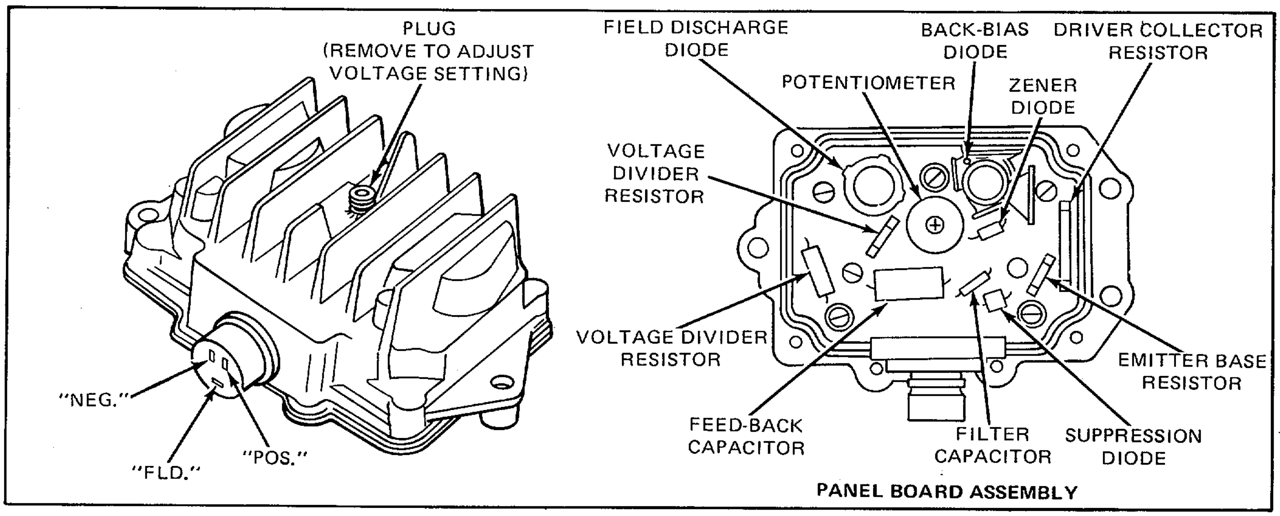


Figure 3. Transistor Regulator with Plug-In Connections

on the generator. The generator then supplies current to charge the battery and operate vehicle accessories.

As generator speed increases, the voltage reaches the preset value and the components in the regulator cause transistor TR-1 to alternately turn off and turn on the generator field voltage. The regulator thus operates to limit the generator output voltage to the preset value.

REGULATOR PRECAUTIONS

Never short or ground the regulator terminals; DO NOT attempt to polarize the circuit.

Make sure all connections in the charging circuit are tight to minimize resistance. Refer to *Alternator Precautions* in *Battery Charging Alternator*.

STORAGE BATTERY

The lead-acid storage battery is an electrochemical device for converting chemical energy into electrical energy.

Function of Battery

The battery has three major functions:

1. It provides a source of current for starting the engine.

2. It acts as a stabilizer to the voltage in the electrical system.

3. It can, for a limited time, furnish current when the electrical demands exceed the output of the generator.

Types of Batteries

There are two types of batteries in use today.

1. The dry charge battery contains fully charged positive plates and negative plates separated by separators. The battery contains no electrolyte until it is activated for service in the field and therefore leaves the factory dry. Consequently, it is called a dry charge battery.

2. If the battery has been manufactured as a wet battery, it will contain fully charged positive and negative plates plus an electrolyte. This type of battery will not maintain its charged condition during storage and must be charged periodically to keep it ready for service.

NOTE

> In the selection of a replacement battery, it is always good practice to select one of an "electrical size" (refer to chart) at least equal to the battery originally engineered for the particular equipment by the manufacturer.

Install Battery

While the battery is built to satisfactorily withstand the conditions under which it will normally operate, excessive mechanical abuse leads to early failure.

Install the battery as follows:

1. Be sure the battery carrier is clean and that the battery rests level when installed.

2. Tighten the hold down clamps evenly until snug. However, do not draw them down too tight or the battery case will become distorted or will crack.

3. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition. To make the cable connections as corrosion resistant as possible, place a felt washer at the base of each terminal, beneath the cable clamps. Coat the entire connection with a heavy general-purpose grease. Be sure the ground cable is clean and tight at the engine block or frame.

BATTERY RECOMMENDATIONS

12 Volt Batteries					
Engine	Starting Motor Voltage	Qty.	S.A.E. Cold Cranking AMP @ 0°F (-17.8°C) AMP Per Battery	Total S.A.E. Cold Cranking AMP @ 0°F (-17.8°C) AMP Per Bank	Reference S.A.E 20AMP Hour Rate Per Bank
4-53	12V	1	600	Single Battery	150

4. Check the polarity to be sure the battery is not reversed with respect to the generating system.

5. Connect the grounded terminal of the battery last to avoid short circuits which will damage the battery.

Servicing the Battery

A battery is a perishable item which requires periodic servicing. Only when the battery is properly cared for as described below can long and trouble free service be expected.

1. Check the level of the electrolyte regularly. Add water if necessary, but do not overfill. Overfilling can cause poor performance or early failure.

2. Keep the top of the battery clean. When necessary, wash with a baking soda solution and rinse with fresh water. Do not allow the soda solution to enter the cells.

3. Inspect the cables, clamps and hold down bracket regularly. Clean and reapply a coat of grease when needed. Replace corroded or damaged parts.

4. Use the standard battery test as the regular service test to check the condition of the battery.

5. Check the electrical system if the battery becomes discharged repeatedly.

Many electrical troubles caused by battery failures can be prevented by systematic battery service. In general, the care and maintenance recommendations for storage batteries are the same today as they have always been.

Battery Safety Precautions

When batteries are being charged, an explosive gas mixture forms beneath the cover of each cell. Part of this gas escapes through the holes in the vent plugs and may form an explosive atmosphere around the battery itself if ventilation is poor.

WARNING

Explosive gas may remain in and around the battery for several hours after it has been charged. Sparks or flames can ignite this gas causing an explosion which could shatter the battery. Flying pieces of the battery structure and splash of electrolyte can cause personal injury.

STARTING MOTOR

The starting motor is mounted on the flywheel housing as illustrated in Fig. 1. When the starting circuit is closed, a small drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from over speeding and damaging the starting motor. To accomplish this, the starting motor is equipped with a Sprag-type overrunning clutch.

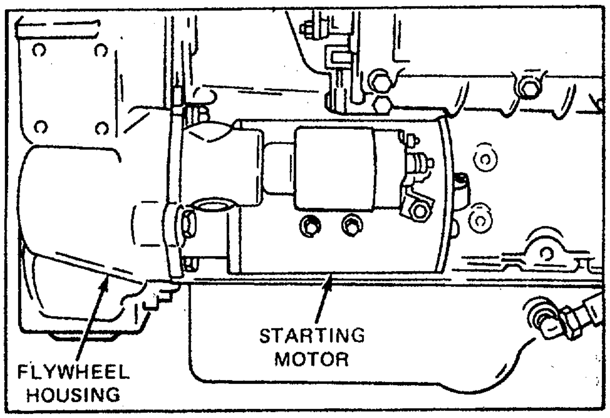


Figure 1. Starting Motor Mounting

A solenoid switch, mounted on the starting motor housing, operates the Sprag-type overrunning clutch drive by linkage and a shift lever (Fig 2).

When the starting switch is engaged, the solenoid is eneirgi2ed and shifts the starting motor pinion into mesh with the: flywheel ring gear and closes the main contacts within the solenoid. Once engaged, the clutch will not disengage during intermittent engine firing. To protect the armature from excessive speed when the engine starts, the clutch overrules, or turns faster than the armature, which permits the pinion to disengage itself from the flywheel ring gear.

The solenoid plunger and shift lever is totally enclosed to protect them from dirt, water, and other foreign material.

The nose housing an the Sprag clutch-type starting motor can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. When repositioning of the solenoid is required on a service replacement starting motor, proceed as follows:

Starter with Intermediate-Duty Clutch (In-Line Engines)

The lever housing and the commutator end frame are held to the field frame by bolts extending from the end frame

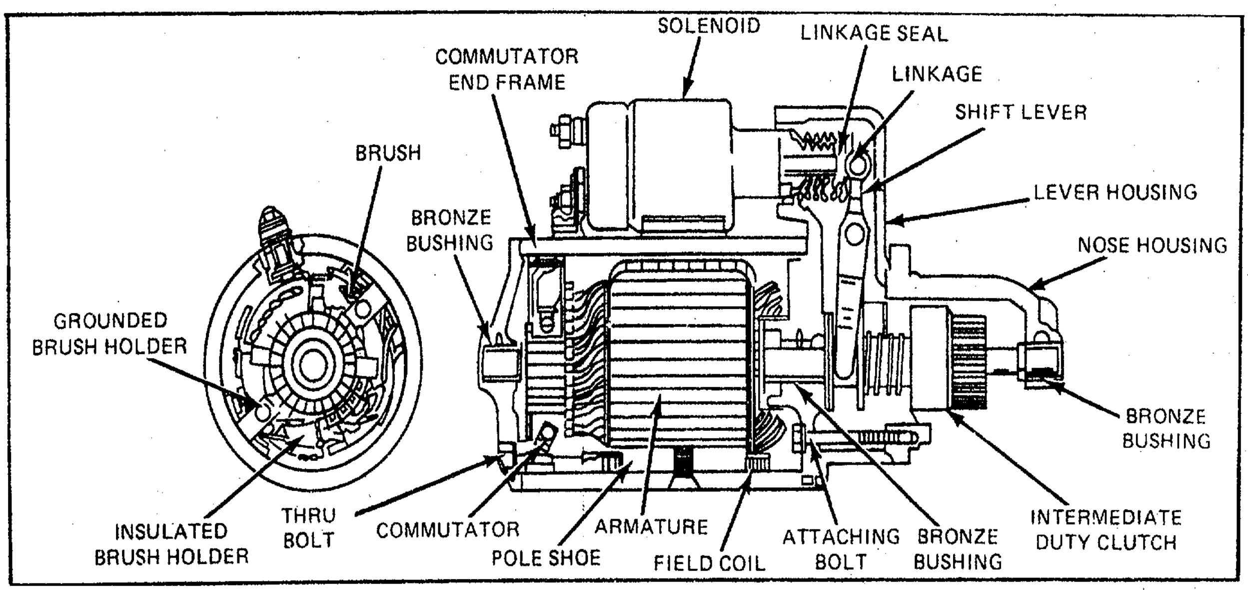


Figure 2 . Cross-Section of Motor with Intermediate-Duty Clutch

to threaded holes in the lever housing. The nose housing is held to the lever housing by internal attaching bolts extending from the lever housing to threaded holes in the nose housing (Fig. 2). With this arrangement, it is necessary to partially disassemble the motor to provide access to the nose housing attaching bolts. Relocate the nose housing as follows:

1. Remove the electrical connector and the screws attaching the solenoid assembly to the field frame. Then remove the bolts from the commutator end frame.

2. Separate the field frame from the remaining assembly and pull the armature away from the lever housing until the pinion stop rests against the clutch pinion. This will provide access to the nose-housing attaching bolts.

3. Remove the nose-housing attaching bolts with a box wrench or open-end wrench.

4. Turn the nose housing to the required position.

CAUTION

The solenoid must never be located below the centerline of the starter or dust, oil, moisture, and foreign material can collect and cause solenoid failures.

5. Reinstall the nose-housing attaching bolts and tighten them to 11-15 lb ft torque.

6. Reassemble the motor.

Lubrication

The starting motor bearings (bushings) are lubricated by oil-saturated wicks which project through each bronze bushing (one at each end and one at the center) and contact the armature shaft.

Oil can be added to each wick by removing a pipe plug which is accessible on the outside of the motor (refer to Lubrication and Preventive Maintenance).

Flywheel Ring Gears

The starting motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth. Flywheel ring gear teeth have either no chamfer or a Bendix chamfer. The Sprag clutch cannot be used with a ring gear with a Dyer chamfer.

Remove Starting Motor

Failure of the starting motor to crank the engine at normal cranking speed may be due to a defective battery, worn battery cables, poor connections in the cranking circuit, defective engine starting switch, low temperature, condition of the engine, or a defective starting motor.

If the engine, battery, and cranking circuit are in good condition, remove the starting motor as follows:

1. Remove the ground strap or cable from the battery or the cable from the starting-motor solenoid. Tape the end of the cable to prevent discharging the battery from a direct short.

2. Disconnect the starting-motor cables and solenoid wiring.

CAUTION

Tag each lead to ensure correct connections when the starting motor is reinstalled.

3. Support the motor and remove the three bolts and lockwashers which secure it to the flywheel housing. Then pull the motor forward to remove it from the flywheel housing.

Check the starting motor, if required, in accordance with the Delco-Remy "Cranking Circuit" maintenance handbook.

Install Starting Motor

To install the starting motor, reverse the procedure outlined for removal.
Tighten the 5/8-11 starter attaching bolts to 137-147 lb ft torque.

Keep all of the electrical connections clean and tight. When installing wiring terminal leads to the starting motor and the solenoid switch, tighten the No. 10-32 connections to 16-30 lb in. torque and the 1/2 x 13 connections to 20-25 lb ft torque.

INSTRUMENTS AND TACH01ETER DRIVE

The instruments (Fig. 1) generally required in the operation of a diesel engine consist of an oil pressure gage, water temperature gage, an ammeter and a mechanical tachometer. Instruments with slotted cases are available for use with lighted dashes. Also, closely related and usually installed in the general vicinity of these instruments are certain controls consisting of an engine starting switch, engine stop knob and an emergency stop knob.

All Torqmatic converters are equipped with an oil pressure gage and, in some instances, with an oil temperature gage. These instruments are mounted on a separate panel.

Instruments, throttle control, and engine starting and stopping controls are mounted in various locations depending upon the particular use of the engine.

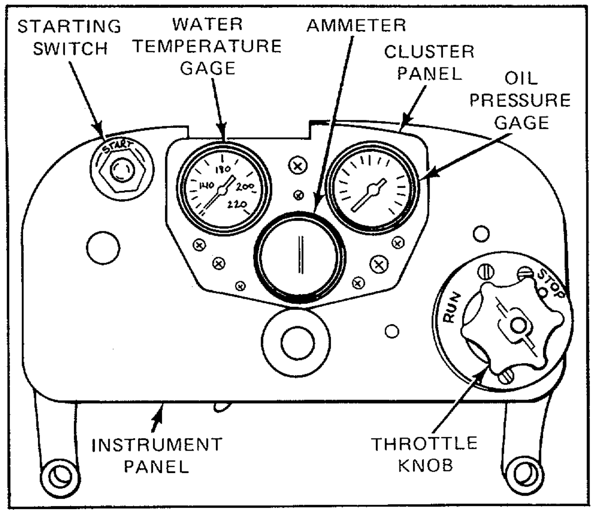


Figure 1. Typical Instrument Panel

Antivibration Instrument Mountings

Antivibration mountings are used in many places to absorb engine vibration in the mounting of instruments, drop relays, tachometers, etc. When it may become necessary to service a part secured by rubber mounts, care should be exercised, during removal and installation of the part, so twist is not imposed into the rubber mount diaphragm. At the time the part is removed from the engine for service, the mounts should be inspected for damage and replaced, if necessary.

The attaching screw, through the center of the mount, must be held from turning during final tightening of the nut. Support the screw and tighten the nut only. If this screw turns, it will preload the rubber diaphragm in torsion and considerably shorten the life of the mount.

Oil Pressure Gage

The oil pressure gage registers the pressure of the lubricating oil in the engine. As soon as the engine is started, the oil pressure gage should start to register. If the oil pressure gage does not register at least the minimum pressure listed in the Operating Condition, the engine should be stopped and the cause of the low oil pressure determined and corrected before the engine is started again.

Current oil pressure gages have male threads and require female fittings. When replacing a former gage with female threads, a new mounting clamp and connector must be used.

Water Temperature Gage

The engine coolant temperature is registered on the water temperature gage.

Incorrect coolant temperature readings will be registered if the gage assembly is incorrectly installed or the capillary tube is damaged.

To prevent damage to the gage assembly from vibration, the capillary tube must be securely fastened to the engine the full length with suitable clips at intervals of ten inches or less. Sharp bends in the tube must be avoided, particularly at the gage or bulb connection areas. Where the tube must be bent around any object, the bend must not be less than one inch radius.

Any extra length can be taken up by coiling, the diameter of which should not be less than two inches. The coils must be located so that they may be securely fastened to prevent vibrating.

Ammeter

The ammeter is wired into the electrical circuit to show the current flow to and from the battery. After starting the engine, the ammeter should register a high charge rate at rated engine speed. This is the rate of charge received by the battery to replenish the current used to start the engine. As the engine continues to operate, the ammeter should show a decline in the charge rate to the battery. The ammeter will not show zero charge rate since the regulator voltage is set higher than the battery voltage. The small current registered prevents rapid brush wear in the battery-charging alternator. If lights or other electrical equipment are connected into the circuit, then the ammeter will show discharge when these items are operating and the engine speed is reduced.

Tachometer

The tachometer, driven by the engine, registers the speed of the engine in revolutions per minute (rpm).

Throttle Control

The engine throttle is connected to the governor speed control shaft through linkage. Movement of the speed control shaft changes the speed setting of the governor and thus the engine speed.

Engine Starting Switch

To start the engine, a switch (Fig. 2) is used to energize the starting motor. Starting switches may vary in design and their contacts must be rated sufficiently to carry the starter solenoid current.

NOTE

Tighten the starting-switch mounting nut to 36-48 lb in. (4-5.5 Nm).

Engine Stop Knob

A stop knob is used to stop the engine. When stopping an engine, the engine speed should be reduced to idle and the engine allowed to operate at idle for a few minutes to permit the coolant to reduce the temperature of the engine's moving parts. Then pull the stop knob and hold it until the engine stops. Pulling on the stop knob manually places the injector racks in the no-fuel position. Return the stop knob to its original position after the engine stops.

Emergency Stop Knob

In an emergency, or if the engine continues to operate after pulling the stop knob, the emergency stop knob may be used to stop the engine. When the emergency stop knob is pulled, the air

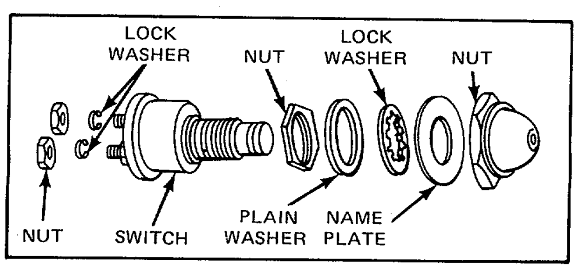


Figure 2. Typical Engine Starting Switch

shutoff valve, located between the air intake and the blower, will trip and shut off the air supply to the engine. Lack of air to the engine will prevent further combustion of the fuel and stop the engine.

The emergency stop knob must be pushed back in after the engine is stopped and the air shutoff valve must be reset manually. The cause of the malfunction should be determined before the engine is started again.

TACHOMETER DRIVE

The tachometer drive shaft is pressed into the end of the camshaft, balance shaft, or governor drive shaft.

When required, a tachometer drive cable adaptor is used to change speed or to change direction of rotation, depending upon the location of the tachometer drive. A special key is used to connect the drive shaft to the tachometer drive cable adaptor.

The cable connection at the current tachometer head is a 5/8 inch threaded connection in place of the former 7/8 inch connection. To eliminate possible misalignment, the current tachometer angle drive has a short flexible cable and incorporates an integral oil seal. The output-shaft key size has been increased from 5/32 inch to SAE 3/16 inch. New flexible drive cables are also required with the current tachometers and angle drives.

Remove Tachometer Drive Shaft

If threads (5/16-24 or 3/8-24) are provided on the outer end of the tachometer drive shaft to accommodate a removing tool, thread remover J 5901-3, on the shaft. Then attach slide hammer J 23907-1 to the remover. A few sharp blows of the weight against the slide hammer rod will remove the tachometer drive shaft.

If threads are not provided on the outer end of the tachometer drive shaft, or if the end of the shaft is broken off, drill and tap the shaft. Then thread a stud into the shaft and remove the shaft with the remover and slide hammer.

CAUTION

> Use adequate protective measures to prevent the metal particles from falling into the gear train and oil pan.

When installing a tachometer drive cover assembly or a drive adaptor, it is important they be aligned properly with the tachometer drive shaft.

ENGINE PROTECTIVE SYSTEMS

MANUAL SHUTDOWN

A manually operated emergency engine shutdown device enables the engine operator to stop the engine in the event an abnormal condition should arise. If the engine continues to run after the engine throttle is placed in the no-fuel position, or if combustible liquids or gases are accidentally introduced into the combustion chamber causing overspeeding of the engine, the shutdown device will prevent damage to the engine by cutting off the air supply and thus stopping the engine. The shutdown device consists of an air shutoff valve mounted in the air inlet housing and a suitable operating mechanism.

Operation

The manually operated shutdown device is operated by a knob located on the instrument panel and connected to the air shutoff valve shaft lever by a control wire. Pulling the knob all the way out will stop the engine. Push the knob all the way in and manually reset the air shutoff valve before starting the engine again.

Service

For disassembly and assembly of the shutdown device, refer to *Air Shutdown Housing*.

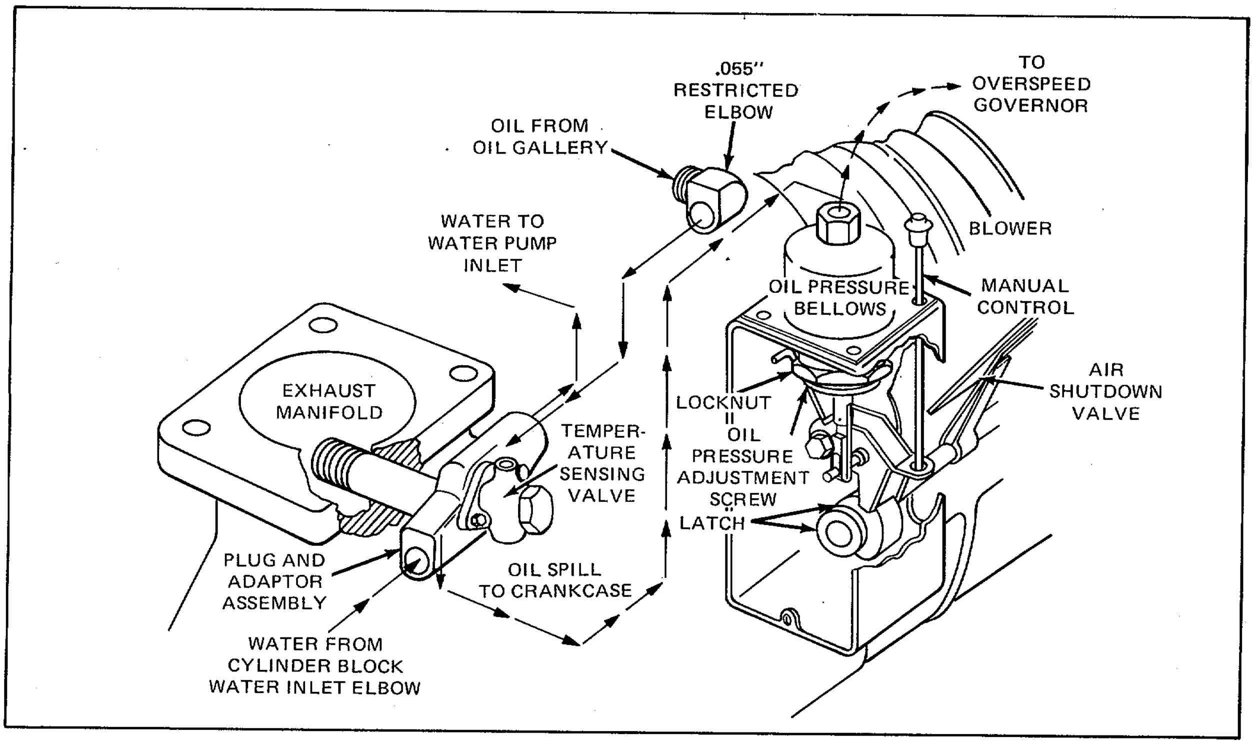


Figure 1. Mechanical Shutdown System Schematically Illustrated

CHECK ENGINE STARTING SWITCH

If difficulty in starting motor engagement has been experienced in a vehicle which has been repowered by a diesel engine, check to see if the key-type starting switch on the instrument panel has been retained.

Key-type starting switches are usually not capable of carrying the current required for heavy-duty diesel engine starter solenoids. The excessive voltage drop in the solenoid circuit restricts the solenoid pull and results in failure of the starter to engage and crank. When tooth abutment occurs and the switch is turned off and on several times, breaking of the solenoid current causes burning or welding of the switch contacts.

Install a push button type starting switch which is capable of making, breaking, and carrying the solenoid current without damage (refer to *Engine Starting Switch* in *Instruments*). Otherwise, a heavy-duty magnetic switch should be used in the solenoid control circuit in addition to the key-type switch. The magnetic switch must be capable of making and breaking at least 90 amperes in a 12-volt system; the key switch would then carry no more than one ampere, which is sufficient to operate the magnetic switch.

ALIGNMENT TOOLS FOR TACHOMETER DRIVE COVERS AND ADAPTORS

Whenever a tachometer drive cover assembly or a tachometer drive adapter is installed on an engine, it is important that the cover assembly or adapter be aligned properly with the tachometer drive shaft.

Misalignment of a tachometer drive shaft can impose a side load on a tachometer drive cable adapter resulting in possible gear seizure and damage to other related components.

To establish proper alignment, use one of the three tools in set J 23068. Because of the many different combinations of tachometer drive shafts, covers, and adapters, it is not practical to itemize specific usages for each tool. When confronted with an alignment job, test fit each tool to determine which provides the best fit and proceed to make the alignment with that tool as shown in Fig. 1.

Correct alignment is established when there is no tachometer drive shaft bind on the inside diameter of the tool when one complete hand rotation of the engine is made.

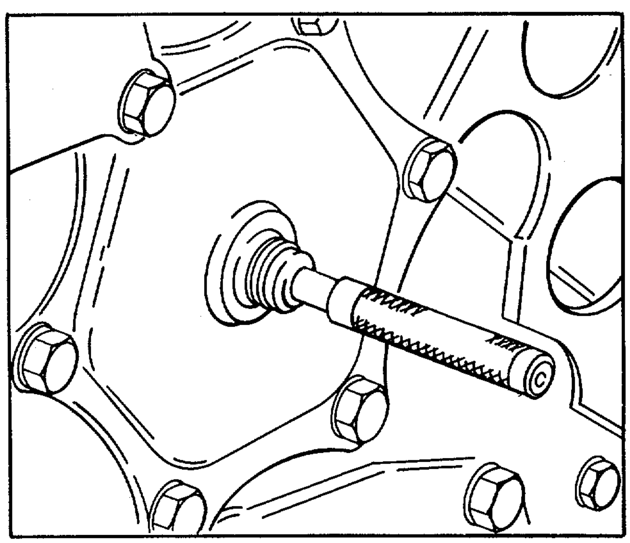


Figure 1. Checking Tachometer Drive Shaft Alignment

ELECTRICAL SYSTEM TROUBLESHOOTING

CHECKING ENGINE ELECTRICAL GENERATING SYSTEM

Whenever trouble is indicated in the electrical generating system, the following quick checks can be made to assist in localizing the cause.

1. A fully charged battery and low charging rate indicates normal generator-regulator operation.

2. A low battery and high charging rate indicates normal generator- regulator operation.

3. A fully charged battery and a high charging rate condition usually indicates the voltage regulator is set too high or is not limiting the generator output. A high charging rate to a fully charged battery will damage the battery and other electrical components.

4. A low battery and low or no charging rate could be caused by: Loose connections or damaged wiring, defective battery or generator, generator not or improperly polarized, and defective regulator or improper regulator setting.

STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

THREAD SIZE	260M BOLTS TORQUE (lb ft)	(Nm)	THREAD SIZE	280M OR BETTER TORQUE (lb ft)	(Nm)
1/4-20	5-7	7-9	1/4-20	7-9	10-12
1/4-28	6-8	8-11	1/4-28	810	11-14
5/16-18	10-13	14-18	5/16-18	13-17	18-23
5/16-24	11-14	15-19	5/16-24	15-19	20-26
3/8-16	23-26	31-35	3/8-16	30-35	41-47
3/8-24	26-29	35-40	3/8-24	35-39	47-53
7/16-14	35-38	47-51	7/16-14	46-50	62-68
7/16-20	43-46	58-62	7/16-20	57-61	77-83
1/2-13	53-56	72-76	1/2-13	71-75	96-102
1/2-20	62-70	84-95	1/2-20	83-93	113-126
9/16-12	68-75	92-102	9/16-12	90-100	122-136
9/16-18	80-88	109-119	9/16-18	107-117	146-159
5/8-11	103-110	140-149	5/8-11	137-147	186-200
5/8-18	126-134	171-181	5/8-18	168-178	228-242
3/4-10	180-188	244-254	3/4-10	240-250	325-339
3/4-16	218-225	295-305	3/4-16	290-300	393-407
7/8-9	308-315	417-427	7/8-9	410-420	556-569
7/8-14	356-364	483-494	7/8-14	475-485	644-657
1-8	435-443	590-600	1-8	580-590	786-800
1-14	514-521	697-705	1-14	685-695	928-942

Grade identification markings are normally stamped on the heads of the bolts. To aid identification of the various bolts used in Detroit Diesel engines, refer to the following chart.

BOLT IDENTICATION CHART

Grade Identification Marking on Bolt Head	GM Number	SAE Grade Designatio n	Nominal Size Diameter (inch)	Tensile Strength Min. (psi)
None	GM 255-M	1	No. 6 thru 1 1/2	60,000
None	GM 260-M	2	No. 6 thru 3/4 over 3/4 to 1 1/2	74,000 60,000
Bolts and Screws	GM 280-M	5	No. 6 thru 1 over 1 to 1 1/2	120,000 105,000
Hex Head Sems Only	GM 275-M	5.1	No. 6 thru 3/8	120,000
Bolts and Screws	BM 290-M	7	1/4 thru 1 1/2	133,000
Bolts and Screws	GM 300-M	8	1/4 thru 1 1/2	150,000
Bolts and Screws	GM 455-M	None	No. 6 thru 1 1/2	55,000

EXCEPTIONS TO STANDARD BOLT AND NUT TORQUE SPECIFICATIONS

APPLICATION	THREAD SIZE	TORQUE (lb ft)	TORQUE (Nm)
Tachometer drive cover bolt	7/16 -14	30-35	41-47
Tachometer drive cover bolt	1/2 -13	30-35	41-47
Starting motor connector	1/2 -13	20-25	27-34
Starting motor connector	No. 10-32	*	*
Tachometer drive shaft (blower)	1/2 -20	55-65	75-88
Starting motor switch mounting nut	5/8 -32	§	§

*16-30 lb in. (2-3.5 Nm)
§36-48 lb in. (4-5.5 Nm)

SERVICE TOOLS

TOOL NAME	TOOL NO.
Puller set	J 5901-01
Slide hammer and shaft	J 23907-1
Tachometer drive shaft remover	J 5901-3
Tachometer drive alignment tool set	J 23068

ENGINE OPERATING CONDITIONS SPECIFICATIONS

	2200 rpm	2500 rpm	2800 rpm
Lubrication System			
Lubricating oil pressure (psi):			
Normal	40-60	40-60	40-60
Minimum for safe operation	30	32	32
*Lubricating oil temperature (degrees F) - max	200-235	200-235	205-240
Air System			
Air box pressure (inches mercury) - min. at full load:			
At zero exhaust back pressure	3.7	4.8	6.1
At maximum exhaust back pressure	5.4	8.0	9.3
Air inlet restriction (inches water) - full load max.:			
Dirty air cleaner - oil bath or dry type	18.8	23.0	25.0
Clean air cleaner - oil bath or dry type with precleaner	12.0	14.0	16.0
Clean air cleaner - dry type without precleaner	7.4	8.7	10.0
Crankcase pressure (inches water) - max	0.8	0.9	1.0
✓Crankcase pressure (inches water) - max	1.1	1.2	1.3
Exhaust back pressure (inches mercury) max.:			
Full load	3.0	†4.0	+4.0
No load	2.1	†2.7	++2.7
Fuel System			
Fuel pressure at inlet manifold (psi):			
Normal with 0.070 inch restriction	45-70	45-70	45-70
Minimum	35	35	35
Fuel spill (gpm) - minimum at no-load:			
0.070 inch restriction	0.6	0.6	0.6
Pump suction at inlet (inches mercury) - max.:			
Clean system	6.0	6.0	6.0
Dirty system	12.0	12.0	12.0
Cooling System			
Coolant temperature (degrees F.) - normal	160-185	160-185	160-185
@Coolant temperature (degrees F.) - normal	170-195	170-195	170-195
Raw water pump:			
Inlet restriction (inches mercury) - max.	†5.0	†5.0	5.0
Outlet pressure (psi) - max.	†10.0	†10.0	10.0
Keel cooler pressure drop (psi):			
Maximum through system	†6.0	†6.0	6.0

Compression
Compression pressure (psi at sea level):
Average - new engine - at 600 rpm 480
Minimum - at 600 rpm 430

*The lubricating oil temperature range is based on the temperature measurement in the oil pan at the oil pump inlet. When measuring the oil temperature at the cylinder block oil gallery, it will be 10° lower than the oil pan temperature.
@Vehicle engines built in 1976 and later.
✓For 53 N engines with front cover breathing systems only.
†Maximum when this is the full-load engine speed.

ENGINE RUN-IN INSTRUCTIONS

Following a complete overhaul or any major repair job involving the installation of piston rings, pistons, cylinder liners, or bearings, the engine should be run-in on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine. It permits the serviceman to physically and visually inspect and check the engine while it is operating. It is an excellent method of detecting improper tuneup, misfiring injectors, low compression, and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear. Normal coolant temperature (160-185°F or 71-85°C) should be maintained throughout the run-in.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 10°F or 6°C higher than the water inlet temperature. Though a 10°F or 6°C rise across an engine is recommended, it has been found that a 15°F or 8°C temperature rise maximum can be permitted.

Thermostats are used in the engine to control the coolant flow. Therefore, be sure they are in place and fully operative or the engine will overheat during the run-in. However, if the dynamometer has a water standpipe with a temperature control regulator, such

BASIC ENGINE RUN-IN SCHEDULE

ENGINE BRAKE HORSEPOWER
4-Valve Cylinder Head

Time Minutes	Speed RPM	Injector Size	4-53 NA
10	600	All	0
10	1500	All 5A50 5A55	20
10 10	Rated Speed Rated Speed	5A60 N-65 5N65* 5A50 5A55 5A60 N-65 5N65*	
120	2000	All	
30	2200	All	87
120	2200	All	
30	2800	All	115
Power Check	Rated Speed	All	Final BHP to be within ±5% of rated

After run-in DO NOT run continuous full load during first 10 hours or 500 miles.
“O” BHP indicates running at no-load for specified time and speed.

as a Taylor valve or equivalent, the engine should be tested without thermostats.

The *Basic Engine Run-In Schedule* is shown in the following table. The horsepower shown is at SAE conditions: dry air density .0705 lb/cu. ft. (1.129 Kg/cu.m) air temperature of 85°F (29.4°C) and 500 ft. elevation.

DYNAMOMETER TEST AND RUN-IN PROCEDURES

The Basic Engine

The great number of engine applications make any attempt to establish comparisons for each individual model impractical. For this reason, each model has a basic engine rating for comparison purposes.

A basic engine includes only those items actually required to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the *Basic Engine Run-In Schedule*. The following items are included on the basic engine: blower, fuel pump, water pump, and governor. The fan and battery-charging alternator typify accessories not considered on the basic engine.

In situations where other than basic engine equipment is used during the test, proper record of this fact should be made on the *Engine Test Report*. The effects of this additional equipment on engine performance should then be considered when evaluating test results.

Dynamometer

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, engine mounts, the absorption unit, a heat exchanger, and a torque loading and measuring device.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb ft or Nm) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula:

$$BHP = (T \times RPM)/5250$$

<u>Where</u>

BHP = brake horsepower
T = torque in lb ft or Nm
RPM = revolutions per minute

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an *Engine Test Report* (see sample on page x).

Instrumentation

Certain instrumentation is necessary so that data required to complete the *Engine Test Report* may be obtained. The following list contains both the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

a. Oil pressure gage installed in one of the engine main oil galleries.

b. Oil temperature gage installed in the oil pan, or thermometer installed in the dipstick hole in the oil pan.

c. Adapter for connecting a pressure gage or mercury manometer to the engine air box.

d. Water temperature gage installed in the thermostat housing.

e. Adapter for connecting a pressure gage or water manometer to the crankcase.

f. Adapter for connecting a pressure gage or mercury manometer to the exhaust manifold at the flange.

g. Adapter for connecting a vacuum gage or water manometer to the blower inlet.

h. Adapter for connecting a fuel- pressure gage to the fuel manifold-inlet passage.

i. Adapter for connecting a pressure gage or mercury manometer to the turbo-charger.

In some cases, gages reading in pounds per square inch or kilopascals are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in psi or kPa, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Inches of water	=	psi x 27.7 inches
Inches of mercury	=	psi x 2.04 inches
Inches of water	=	kPa x 4.02 inches
Inches of mercury	=	kPa x 0.30 inches

CAUTION

Before starting the run-in or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions on *Preparation to Start Engine First Time* in *Chapter II Operations.*

Run-In Procedure

The procedure outlined below will follow the order of the sample *Engine Test Report*.

A. PRESTARTING

1. Fill the lubrication system as outlined under *Lubrication System -- Preparation to Start Engine First Time* in *Chapter II Operations*.
2. Prime the fuel system as outlined under *Fuel System -- Preparation to Start Engine First Time* in *Chapter II Operations.*
3. A preliminary valve clearance adjustment must be made before the engine is started. *Refer to Exhaust Valve Clearance Adjustment*.
4. A preliminary injector timing check must be made before starting the engine. *Refer to Fuel Injector Timing*.
5. Preliminary governor adjustments must be made. *Refer to Governor and Injector Rack Control Adjustment*.
6. Preliminary injector rack adjustment must be made. *Refer to Governor and Injector Rack Control Adjustment.*

B. BASIC ENGINE RUN-IN

The operator should be observant at all times, so that any malfunction which may develop will be detected.

Since the engine has just been reconditioned, this run-in will be a test of the workmanship of the serviceman who performed the overhaul. Minor difficulties should be detected and corrected so that a major problem will not develop.

After performing the preliminary steps, be sure all water valves, fuel valves, etc. are open. Also inspect the exhaust system, being sure that it is properly connected to the engine. Always start the engine with minimum dynamometer resistance.

After the engine starts, if using a water brake type dynamometer, allow sufficient water, by means of the control loading valves, into the dynamometer absorption unit to show a reading of approximately 5 lb ft (7 Nm) on the torque gage (or 10-15 HP on a horsepower gage). This is necessary, on some units, to lubricate the absorption unit seals and to protect them from damage.

Set the engine throttle at idle speed, check the lubricating oil pressure and check all connections to be sure there are no leaks.

Refer to the *Engine Test Report* sample which establishes the sequence of events for the test and run-in, and to the *Basic Engine Run-In Schedule* which indicates the speed (rpm), length of time, and the brake horsepower required for each phase of the test. Also refer to the *Engine Operating Conditions Specifications* which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power.

Engine governors in most cases must be reset at the maximum full-load speed designated for the run-in. If a governor is encountered which cannot be adjusted to this speed, a stock governor should be installed for the run-in.

After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the *Basic Engine Run-In Schedule*.

The engine should be run at this speed and load for 10 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length of time, speed, brake horsepower, coolant temperature, and lubricating oil pressure on the *Engine Test Report*.

Run the engine at each speed and rating for the length of time indicated in the *Basic Engine Run-In Schedule*.

This is the basic run-in. During this time, engine performance will improve as new parts begin to "seat in". Record all of the required data.

C. BASIC RUN-IN INSPECTION

While the engine is undergoing the basic run-in, check each item indicated in section C of the *Engine Test Report*. Check for fuel oil or water leaks in the rocker arm compartment.

During the final portion of the basic run-in, the engine should be inspected for fuel oil, lubricating oil, and water leaks.

Upon completion of the basic run-in and inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.

D. INSPECTION AFTER BASIC RUN-IN

The primary purpose of this inspection is to provide a fine engine tuneup. First, tighten the cylinder head and rocker arm shaft bolts to the proper torque. Next, complete the applicable tuneup procedure. Refer to *Engine Tuneup*.

E. FINAL RUN-IN

After all of the tests have been made and the *Engine Test Report* is completed through Section D, the engine is ready for final test. This portion of the test and run-in procedure will assure the engine owner that his engine has been rebuilt to deliver factory-rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shutdown for one hour or longer, it will be necessary to have a warm-up period of 10 minutes at the same speed and load used for warm-up in the basic run-in. If piston rings, cylinder liners, or bearings have been replaced as a result of findings in the basic run-in, the entire basic run-in must be repeated as though the run-in and test procedure were started anew.

All readings observed during the final run-in should fall within the range specified in the *Engine Operating Conditions Specifications* and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

The engine water temperature should be taken during the last portion of the basic run-in at full load. It should be recorded and should be within the specified range.

The lubricating oil temperature reading must be taken while the engine is operating at full load and after it has been operating long enough for the temperature to stabilize. This temperature should be recorded and should be within the specified range.

The lubricating oil pressure should be recorded in psi or kPa after being taken at engine speeds indicated in the *Engine Operating Conditions Specifications*.

The fuel oil pressure at the fuel manifold inlet passage should be recorded and should fall within the specified range. Fuel pressure should be recorded at maximum engine speed during the final run-in.

Check the air box pressure while the engine is operating at maximum speed and load. This check may be made by attaching a suitable gage (0-15 psi or 0-103 kPa) or manometer (15-0-15) to an air box drain or to a handhole plate prepared for this purpose. If an air box drain is used as a source for this check, it must be clean. The air box pressure should be recorded in inches of mercury.

Check the crankcase pressure while the engine is operating at maximum run-in speed. Attach a manometer, calibrated to read in inches of water, to the oil level dipstick opening. Normally, crankcase pressure should decrease during the run-in indicating that new rings are beginning to “seat-in".

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2 inches above the air inlet housing. When practicability prevents the insertion of a fitting at this point, the manometer may be connected to a fitting installed in the 1/4 inch pipe-tapped hole in the engine air inlet housing. If a hole is not provided, a stock housing should be drilled, tapped, and kept on hand for future use.

The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading. On turbocharged engines, take the reading on the inlet side of the turbocharger. The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting.

Check the normal air intake vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions Specifications*. Record these readings on the *Engine Test Report*.

Check the exhaust back pressure (except turbocharged engines) at the exhaust manifold companion flange or within one inch of this location. This check should be made with a mercury manometer through a tube adapter installed at the tapped hole. If the exhaust manifold does not provide a 1/8 inch pipe-tapped hole, such a hole can be incorporated by reworking the exhaust manifold. Install a fitting for a pressure gage or manometer in this hole. Care should be exercised so that the fitting does not protrude into the stack. On turbocharged engines, check the exhaust back pressure in the exhaust piping 6 to 12 inches from the turbine outlet. The tapped hole must be in a comparatively straight area for an accurate measurement. The manometer check should produce a reading in inches that is below the Maximum Exhaust Back Pressure for the engine (refer to Engine Operating Conditions Specifications).

Turbocharger compressor outlet pressure and turbine inlet pressures are taken at full-load and no-load speeds.

Refer to the *Engine Run-In Schedule* and determine the maximum rated brake horsepower and the full-load speed to be used during the final run-in. Apply the load thus determined to the dynamometer. If a hydraulic governor is used, the droop may be adjusted at this time by following the prescribed procedure. The engine should be run at this speed and load for 1/2 hour. While making the final run-in, the engine should develop, within 5%, the maximum-rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

When the above conditions have been met, adjust the maximum no-load speed to conform with that specified for the particular engine. This speed may be either higher or lower than the maximum speed used during the basic run-in. This will ordinarily require a governor adjustment.

All information required in Section E, Final Run-In, of the *Engine Test Report* should be determined and filled in. After the prescribed time for the final run-in has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine. The final run-in is complete.

F. INSPECTION AFTER FINAL RUN-IN

After the final run-in and before the *Engine Test Report* is completed, a final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rustproofing the fuel system as outlined in *Storage* and adding a rust inhibitor into the cooling system (refer to *Coolant Specifications*). The lubricating oil filters should also be changed.

CAUTION

A rust inhibitor in the coolant system of a Series 53 engine is particularly important because of the wet cylinder liners. Omission of a rust inhibitor will cause rusting of the outside diameter of the cylinder liners and interference with liner heat transfer.

ENGINE TEST REPORT

Date ____________ Unit Number ____________
Repair Order Number ____________ Model Number ____________

A — PRE-STARTING

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL SYSTEM	3. ADJUST VALVES	4. TIME INJ.	5. ADJ. GOV.	6. ADJUST INJ. RACKS

B — BASIC ENGINE RUN-IN

TIME AT SPEED	TIME START	TIME STOP	RPM	BHP	WATER TEMP.	LUBE OIL PRESS.

C — BASIC RUN-IN INSPECTION

1. Check oil at rocker arm mechanism	
2. Inspect for lube oil leaks	
3. Inspect for fuel oil leaks	
4. Inspect for water leaks	
5. Check and tighten all external bolts	
6.	

D — INSPECTION AFTER BASIC RUN-IN

1. Tighten Cylinder Head & Rocker Shaft Bolts		4. Adjust Governor Gap	
2. Adjust Valves (Hot)		5. Adjust Injector Racks	
3. Time Injectors		6.	

E — FINAL RUN-IN

TIME START	TIME STOP	TOP RPM NO LOAD	TOP RPM FULL LOAD	BHP	AIR BOX PRESSURE FULL LOAD	EXHAUST BACK PRESSURE F/L	CRANKCASE PRESSURE F/L

BLOWER INTAKE RES. - F/L	FUEL OIL PRESSURE RET. MAN. F/L	WATER TEMP. FULL LOAD	LUBE OIL TEMP. F/L	LUBE OIL PRESSURE FULL LOAD	LUBE OIL PRESSURE IDLE	IDLE SPEED

F — INSPECTION AFTER FINAL RUN

1. Inspect Air Box, Pistons, Liners, Rings	6. Tighten Oil Pump Bolts
2. Inspect Blower	7. Inspect Oil Pump Drive
3. Check Generator Charging Plate	8. Replace Lube Filter Elements
4. Wash Oil Pan, Check Gasket	9. Tighten Flywheel Bolts
5. Clean Oil Pump Screen	10. Rust Proof Cooling System

REMARKS:

Final Run OK'd ____________ Dynamometer Operator ____________ Date ____________

NOTE: Operator must initial each check and sign this report.

FUEL AND OIL SPECIFICATIONS
DIESEL FUEL OILS
GENERAL CONSIDERATIONS

The quality of fuel oil used for highspeed diesel engine operation is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust.

Fuel selected should be completely distilled material. That is the fuel should show at least 98% by volume recovery when subjected to ASTM D-86 distillation. Fuels marketed to meet Federal Specification VV-F-800 (grades DF-1 and DF-2) and ASTM Designation D-975 (grades I-D and 2-D) meet the completely distilled criteria. Some of the general properties of VV-F-800 and ASTM D-975 fuels are shown below. Residual fuels and domestic furnace oils are not considered satisfactory for Detroit Diesel engines; however, some may be acceptable. (See *Detroit Diesel Fuel Oil Specifications*.)

NOTE

Detroit Diesel Allison does not recommend the use of drained lubricating oil as a diesel fuel oil. Furthermore, Detroit Diesel Allison will not be responsible for any engine detrimental effects which it determines resulted from this practice.

All diesel fuel oil contains a certain amount of sulfur. Too high a sulfur content results in excessive cylinder

FEDERAL SPECIFICATION & ASTM DIESEL FUEL PROPERTIES

Specification or Classification Grade	VV-F-800 DF-1	ASTM D-975 1-D	VV-F-800 DF-2	ASTM D-975 2-D
Flash Point, min.	104°F 40°C	100°F 38°C	122°F 50°C	125°F 52°C
Carbon Residue (10% residuum), % max.	0.15	0.15	0.20	0.35
Water & Sediment, % by vol., max.	0.01	trace	0.01	0.05
Ash. % by wt., max.	0.005	0.01	0.005	0.01
Distillation Temperature,				
90% by vol. recovery, min.	-	-	-	540°F (282°C)
max.	572°F (300°C)	550°F (288°C)	626°F (330°C)	640°F (338°C)
End Point, Max.	626°F (330°C)	-	671°F (355°C)	-
Viscosity 100°F(38°C)				
Kinematic, cs, min.	1.4	1.4	2.0	2.0
Saybolt, SUS, min.	-	-	-	32.6
Kinematic, cs, max.	3.0	2.5	4.3	4.3
Saybolt, SUS, max.	-	34.4	-	40.1
Sulfur, % by wt. max.	0.50	0.50	0.50	0.50
Cetane No.	45	40	45	40

wear due to acid build-up in the lubricating oil. For most satisfactory engine life, fuels containing less than 0.5% sulfur should be used.

Fuel oil should be clean and free of contamination. Storage tanks should be inspected regularly for dirt, water, or water-emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants for storage instability must be resolved with the fuel supplier.

DETROIT DIESEL FUEL OIL SPECIFICATIONS

Detroit Diesel Allison designs, develops, and manufactures commercial diesel engines to operate on diesel fuels classified by the ASTM as Designation D-975 (grades 1-D and 2-D). These grades are very similar to grades DF-1 and DF-2 of Federal Specification VV-F-800. Residual fuels and furnace oils, generally, are not considered satisfactory for Detroit Diesel engines. In some regions, however, fuel suppliers may distribute one fuel that is marketed as either diesel fuel (ASTM D-975) or domestic heating fuel (ASTM D-396) sometimes identified as furnace oil. In this case, the fuel should be investigated to determine whether the properties conform with those shown in the *Fuel Oil Selection Chart* presented in this specification.

The *Fuel Oil Selection Chart* also will serve as a guide in the selection of the proper fuel for various applications. The fuels used must be clean, completely distilled, stable, and noncorrosive. Distillation range, cetane number, and sulfur content are three of the most important properties of diesel fuels that must be controlled to insure optimum combustion and minimum wear. Engine speed, load, and ambient temperature influence the selection of fuels with respect to distillation range and cetane number. The sulfur content of the fuel must be as low as possible to avoid excessive deposit formation, premature wear, and to minimize the sulfur dioxide exhausted into the atmosphere.

To assure that the fuel you use meets the required properties, enlist the aid of a reputable fuel oil supplier. The responsibility for clean fuel lies with the fuel supplier as well as the operator.

During cold weather engine operation, the cloud point (the temperature at which wax crystals begin to form in diesel fuel) should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of the fuel filters by wax crystals.

At temperatures below -20°F (-29°C), consult an authorized Detroit Diesel Allison service outlet, since particular attention must be given to the cooling system, lubricating system, fuel system, electrical system, and cold weather starting aid for efficient engine starting and operation.

NOTE

> When prolonged idling periods or cold weather conditions below 32°F (0°C) are encountered, the use of lighter distillate fuels may be more practical. The same consideration must be made when operating at altitudes above 5000 feet.

DIESEL LUBRICATING OILS
GENERAL CONSIDERATIONS

All diesel engines require heavy-duty lubricating oils. Basic requirements of such oils are lubricating quality, high heat resistance, and control of contaminants.

Lubricating Quality: The reduction of friction and wear by maintaining an oil

FUEL OIL SELECTION CHART

Typical Application	General Fuel Classification	Final Boiling Point	Cetane No.	Sulfur Content
City Buses	No. 1-D	(Max) 550°F (288°C)	(Min) 45	(Ma) 0.30%
All Other Applications	Winter No. 2-D Summer No. 2-D	675°F 675°F (357°C)	45 40	0.50% 0.50%

film between moving parts is the primary requisite of a lubricant. Film thickness and its ability to prevent metal-to-metal contact of moving parts is related to oil viscosity. The optimums for Detroit Diesel engines are 15W-40, or SAE 40 or 30 weight.

High Heat Resistance: Temperature is the most important factor in determining the rate at which deterioration or oxidation of the lubricating oil will occur. The oil should have adequate thermal stability at elevated temperatures, thereby precluding formation of harmful carbonaceous and/or ash deposits.

Control Of Contaminants: The piston and compression rings must ride on a film of oil to minimize wear and prevent cylinder seizure. At normal rates of consumption, oil reaches a temperature zone at the upper part of the piston where rapid oxidation and carbonization can occur. In addition, as oil circulates through the engine, it is continuously contaminated by soot, acids, and water originating from combustion. Until they are exhausted, detergent and dispersant additives aid in keeping sludge and varnish from depositing on engine parts. But such additives in excessive quantities can result in detrimental ash deposits. If abnormal amounts of insoluble deposits form, particularly on the piston in the compression ring area, early engine failure may result. Oil that is carried up the cylinder liner wall is normally consumed during engine operation. The oil and additives leave carbonaceous and/or ash deposits when subjected to the elevated temperatures of the combustion chamber. The amount of deposits is influenced by the oil composition, additive content, engine temperature, and oil consumption rate.

DETROIT DIESEL LUBRICATING OIL SPECIFICATIONS

OIL QUALITY

Oil quality is the responsibility of the oil supplier. (The term oil supplier is applicable to refiners, blenders, and rebranders of petroleum products, and does not include distributors of such products).

There are hundreds of commercial crankcase oils marketed today. Obviously, engine manufacturers or users cannot completely evaluate the numerous commercial oils. The selection of a suitable lubricant in consultation with a reliable oil supplier, observance of his oil drain recommendations (based on used oil sample analysis and experience) and proper filter maintenance, will provide the best assurance of satisfactory oil performance.

Detroit Diesel Allison lubricant recommendations are based on general experience with current lubricants of various types and give consideration to the commercial lubricants presently available.

RECOMMENDATION

Detroit Diesel engines have given optimum performance and experienced the longest service life with the following oil performance levels having the ash limits and zinc requirements shown.

15W-40 MULTIGRADE LUBE OIL

Detroit Diesel Allison now approves and recommends the use of the new generation 15W-40 lubrication oils, providing the following ash limits, zinc requirements, oil performance levels, and conditions are met:

1. The sulfated ash (ASTM D-874) content of the lubricant shall not exceed 1.000% by weight, except lubricants that contain only barium detergent-dispersant salts where 1.5% by weight is allowed.
2. The lubricant shall meet the performance requirements shown in API Service Classifications CD/SE.
3. The zinc content (zinc diorganodithiophosphate) of all the lubricants recommended for use in Detroit Diesel engines shall be a minimum of 0.07% by weight. However, the zinc requirement is waived where EMD lubricants are used.
4. Evidence of satisfactory performance in Detroit Diesel engines has been shown to the customer and to Detroit Diesel Allison by the oil supplier.

10W-30, 20W-40 & OTHER MULTIGRADE OILS

Detriot Diesel Allison does NOT approve any multigrade oils, except the new generation 15W-40 lubricants previously described. Although lubricants such as 10W-30 and 20W-40 are commercially available, the performance of their additive systems has not been demonstrated in Detroit Diesel engines. Since properties such as sulfated ash are affected in formulating these multigrade compounds, their use cannot be approved.

SAE-40 & SAE-30 SINGLE GRADE LUBRICANTS

Detroit Diesel Allison continues to approve SAE-40 and SAE-30 lube oils, providing they meet the 1.000% maximum sulfated ash limit, the 0.07% by weight minimum zinc content, and the following API Service Classifications:

API Letter Code Service Class.	Military Specification	SAE Grade
CB	MIL-L-2104A (Supplement 1)	40 or 30
CC	MIL-L-2104B	40 or 30
CD/SC	MIL-L-2104C	40 or 30
CD	MIL-L-45199B (Series 3)	40 or 30
CC/SE	MIL-L-46152	40 or 30
Numerous	Universal	40 or 30

MIL-L-46167 ARCTIC LUBE OILS FOR NORTHR SLOPE & OTHER EXTREME SUB-ZERO OPERATIONS

Lubricants meeting this specification are used in Alaska and other extreme sub-zero locations. Generally, they may be described as 5W-20 multigrade lubricants made up of synthetic base stock and manifesting low volatility characteristics. Although they have been used successfully in some severe cold regions, Detroit Diesel Allison -does not consider their use as desirable as the use of 15W-40 (new generation), SAE-40, or SAE-30 oils with auxiliary heating aids. For this reason, they should be considered only where engine cranking is a severe problem and auxiliary heating aids are not available on the engine.

EMD (RR) OILS

Lubricants qualified for use in Electro-Motive Division (EMD) diesel engines may be used in Detroit Diesel engines provided the sulfated ash (ASTM D-874) content does not exceed 1.000% by weight. These lubricants are frequently desired for use in applications where both Detroit Diesel and Electro-Motive powered units are operated. These fluids may be described as SAE-40 lubricants that possess medium Viscosity Index properties and do not contain any zinc additives.

SYNTHETIC OILS

Synthetic lubricants may be used in Detroit Diesel engines provided the ash limit, zinc requirements, and specified oil performance levels (for example, CD/SE or MIL-L-2104B, etc.) shown elsewhere in this specification are met. Viscosity grades 15W-40 or SAE-40 or SAE-30 are recommended.

EVIDENCE OF SATISFACTORY PERFORMANCE

Detroit Diesel Allison has referred to evidence of satisfactory performance in its lubricant specifications. Detroit Diesel Allison uses controlled field test oil evaluation programs to determine the performance of lubricants. The following briefly describes one method Detroit Diesel Allison uses to evaluate lubricating oil performance.

This method may be used as a guideline for oil suppliers with candidate lubricants for Detroit Diesel engines.

1. Select five highway truck (72,000 lbs GCW) units in the same fleet powered by Detroit Diesel engines. Operate these on the candidate 15W-40 motor oil for 200,000 miles.

2. Select five "sister" highway trucks in the same fleet to operate on a reference SAE-30 or SAE-40 grade lubricant having a history of good performance in Detroit Diesel engines.

3. Operate the 10 oil test engines for 200,000 miles each. Monitor the oil and fuel consumption during the test period. Record any serious mechanical problems experienced. Disassemble all ten engines at the conclusion of the 200,000 mile period and compare the following:

- Ring sticking tendencies and/or ring conditions.
- Piston skirt and cylinder liner scuffing.
- Exhaust valve face and stem deposits.
- Overall wear levels.

4. The results obtained from a new candidate 15W-40 lubricant should be comparable to or better than those obtained from SAE 30 or 40 oils.

ENGINE OIL CLASSIFICATION SYSTEM

The American Petroleum Institute (API), the Society of Automotive Engineers (SAE), and the American Society for Testing and Materials (ASTM) jointly have developed the present commercial system for designating and identifying motor oil classifications. ,The table below shows a cross-reference of current commercial and military lube oil identification and specification systems.

NOTE

MIL-L-2104B lubricants are obsolete for Military service applications only. MIL-L-2104B lubricants are currently marketed and readily available for commercial use.

Consult the following publications for complete descriptions:

1. Society of Automotive Engineers (SAE) Technical Report J-183a.

2. Federal Test Method Standard 791a.

OIL CHANGES

Oil change intervals are dependent upon the various operating conditions of the engines and the sulfur content of the diesel fuel used. Oil drain intervals in all service applications may be increased or decreased with experience using a specific lubricant, while also considering the recommendations of the oil supplier. Generally, the sulfur content of diesel fuels supplied throughout the U.S.A and Canada are low (i.e., less than 0.5% by weight ASTM D-129 or D-1552 or D-2622). Fuels distributed in some overseas locations may contain higher concentrations of sulfur, the use of which will require reduced lube oil drain intervals.

Industrial Series 53 Naturally Aspirated Engines

Series 53, 71, and 92 engines, in industrial service, should be started with 150-hour oil change periods. The oil drain intervals may be extended if supported by used oil analyses.

CROSS REFERENCE OF LUBE OIL CLASSIFICATION SYSTEM

API CODE LETTERS	Comparable Military or Commercial Industry Specification
CA	MIL-L-2104A
CB	Supplement 1
CC	MIL-L-2104B (see note below)
CD	MIL-L-45199B (Series B)
*	MIL-L-46152 (supersedes MIL-L-2104B for Military only)
†	MIL-L-2104C (supersedes MIL-L-45199B for Military only)
SA	none
SB	none
SC	Auto passenger car 1964 MS oils - obsolete system
SD	Auto passenger car 1968 MS oils - obsolete system
SE	Auto passenger car 1972 MS oils - obsolete system

*Oil performance meets or exceeds that of CC and SE oils.
†Oil performance meets or exceeds that of CD and SC oils.

Used Lube Oil Analysis Warning Values

The presence of ethylene glycol in the oil is damaging to the engine. Its presence and need for an oil change and for corrective maintenance action may be confirmed by glycol detector kits which are commercially available.

Fuel dilution of the oil may result from loose fuel connections or from prolonged engine idling. A fuel dilution exceeding 2.57%of volume indicates an immediate need for an oil change and corrective maintenance action. Fuel dilution may be confirmed by ASTM D-322 test procedure performed by oil suppliers or independent laboratories.

In addition to the above considerations, if any of the following occur, the oil should be changed:

1. The viscosity at 100°F of a used oil sample is 40% greater than the viscosity of the unused oil measured at the same temperature (ASTM D-445 and D-2161).

2. The iron content is greater than 150 parts per million.

3. The coagulated pentane insolubles (total contamination) exceed 1.00% by weight (ASTM D-893).

4. The total base number (TBN) is less than 1.0 (ASTM D-664).

NOTE

The sulfur content of the diesel fuel used will influence the alkalinity of the lube oil. With high sulfur fuels, the oil drain interval will have to be shortened to avoid excessive acidity in the lube oil.

LUBE OIL FILTER ELEMENT CHANCES

Full-Flow Filters

A full-flow oil filtration system is used in all Detroit Diesel engines. To ensure against physical deterioration of the filter element it should be replaced at a maximum of 25,000 miles for on-highway vehicles or at each oil change period, whichever occurs first. For all other applications, the filter should be replaced at a maximum of 500 hours or at each oil change period, whichever occurs first.

By-Pass Filters

Auxiliary by-pass lube oil filters are not required on Detroit Diesel engines.

STATEMENT OF POLICY ON FUEL AND LUBRICANT ADDITIVES

In answer to requests concerning the use of fuel and lubricating oil additives, the following excerpt has been taken from a policy statement of General Motors Corporation:

> “It has been and continues to be General Motors policy to build motor vehicles that will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets.”

Therefore, Detroit Diesel Allison does not recommend the use of any supplementary fuel or lubricant additives. These include all products marketed as fuel conditioners, smoke suppressants, masking agents, reodorants, tuneup compounds, top oils, break-in oils, graphitizers, and friction-reducing compounds.

NOTE

The manufacturer's warranty applicable to Detroit Diesel engines provides in part that the provisions of such warranty shall not apply to any engine unit which has been subject to misuse, negligence or accident. Accordingly, malfunctions attributable to neglect or failure to follow the manufacturer's fuel or lubricating recommendations may not be within the coverage of the warranty.

SERVICE AND INSPECTION INTERVALS

Generally, operating conditions will vary for each engine application, even with comparable mileage or hours and therefore, maintenance schedules can vary. A good rule of thumb for piston ring and liner inspections, however, would be at 45,000 miles or 1500 hours for the first such inspection and at 30,000 miles or 1000 hour intervals thereafter.

COOLANT

Engine coolant is considered as any solution which is circulated through the engine to provide the means for heat transfer from the different engine components. In general, water containing various materials in solution is used for this purpose.

The function of the coolant is basic to the design and to the successful operation of the engine. Therefore, coolant must be carefully selected and properly maintained.

COOLANT REQUIREMENTS

A suitable coolant solution must meet the following basic requirements:

1. Provide for adequate heat transfer.
2. Provide a corrosion-resistant environment within the cooling system.
3. Prevent formation of scale or sludge deposits in the cooling system.
4. Be compatible with the cooling system hose and seal materials.
5. Provide adequate freeze protection during cold weather operation.

The first four requirements are satisfied by combining a suitable water with reliable inhibitors. When operating conditions dictate the need for freeze protection, a solution of suitable water and a permanent-type antifreeze containing adequate inhibitors will provide a satisfactory coolant.

WATER

Any water, whether of drinking quality or not, will produce a corrosive environment in the cooling system. Also, scale deposits may form on the internal surfaces of the cooling system due to the mineral content of the water. Therefore, water selected as a coolant must be properly treated with inhibitors to control corrosion and scale deposits.

To determine if a particular water is suitable for use as a coolant when properly inhibited, the following characteristics must be considered: the concentration of chlorides, sulfates, total hardness, and dissolved solids. Chlorides and/or sulfates tend to accelerate corrosion, while hardness (percentage of magnesium and calcium present) causes deposits of scale. Total dissolved solids may cause scale deposits, sludge deposits, corrosion, or a combination of these. Chlorides, sulfates, magnesium, and calcium are among but not necessarily all the materials which makeup dissolved solids. Water, within the limits specified in Tables 1 and 2 of Fig. 1, is satisfactory as an engine coolant when proper inhibitors are added.

CORROSION INHIBITORS

A corrosion inhibitor is a water soluble chemical compound which protects the metallic surfaces of the cooling system against corrosive attack. Some of the more commonly used corrosion inhibitors are chromates, borates, nitrates, nitrites, and soluble oil.

Depletion of all types of inhibitors occur through normal operation. Therefore, strength levels must be maintained by the addition of inhibitors at prescribed intervals. Always follow the supplier's recommendations on inhibitor usage and handling.

Chromates

Sodium chromate and potassium dichromate are two of the best and most commonly used water system corrosion inhibitors. However, the restrictive use of these materials, due to ecology

TABLE 1

	PARTS PER MILLION	GRAINS PER GALLON
Chlorides (Maximum)	40	2.5
Sulfates (Maximum)	100	5.8
Total Dissolved Solids (Maximum)	340	20
Total Hardness (Maximum)	170	10

Refer to Table 2 for evaluation of water intended for use in a coolant solution.

TABLE 2

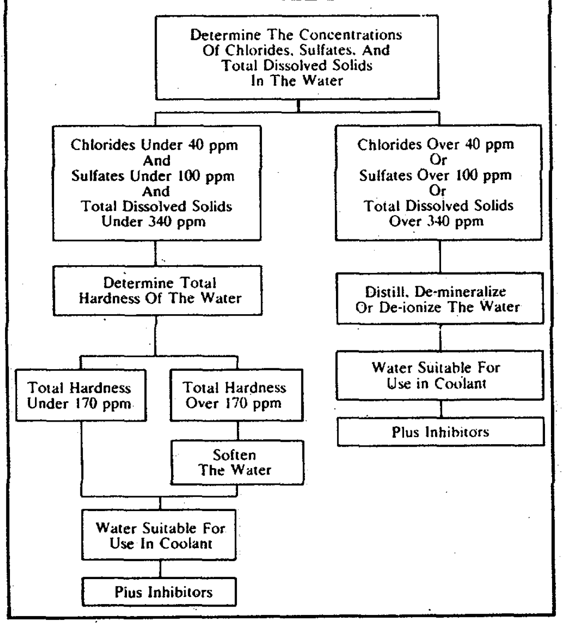


Figure 1. Water Characteristics

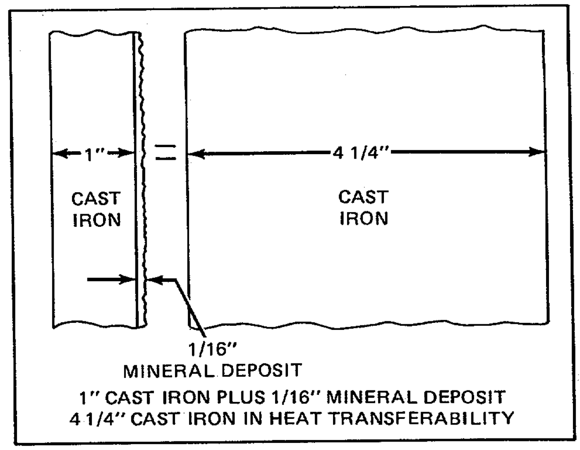


Figure 2. Heat Transfer Capacity

considerations, has deemphasized their use in favor of nonchromates. Care should be exercised in handling these materials due to their toxic nature.

Chromate inhibitors should not be used in permanent-type antifreeze solutions. Chromium hydroxide, commonly called green slime", can result from the use of chromate inhibitors with permanent type antifreeze. This material deposits on the cooling system passages, reducing the heat transfer rate (Fig. 2), and results in engine overheating. Engines which have operated with a chromate-inhibited water must be chemically cleaned before the addition of permanent-type antifreeze. A commercial heavy-duty descaler should be used in accordance with the manufacturer's recommendation for this purpose.

Soluble Oil

Soluble oil has been used as a corrosion inhibitor for many years. It has, however, required very close attention relative to the concentration level due to adverse effects on heat transfer if the concentration exceeds 1% by volume. For example: 1-1/4% of soluble oil in the cooling system increases fire deck temperatures 6% and a 2-1/2% concentration raises fire deck temperature up to 15%. Soluble oil is NOT RECOMMENDED as a corrosion inhibitor.

Nonchromates

Nonchromate inhibitors (borates, nitrates, nitrites, etc.) provide corrosion protection in the cooling system with the basic advantage that they can be used with either water or a water and permanent-type antifreeze solution.

INHIBITOR SYSTEMS

An inhibitor system (Fig. 3) is a combination of chemical compounds which provide corrosion protection, pH control, and water softening ability. Corrosion protection is discussed under the heading *Corrosion Inhibitors*. The pH control is used to maintain an acid free solution. The water softening

		Inhibitor Compatibility		
Inhibitor or Inhibitor System	Corrosion Inhibitor Type	Complete Inhibitor System	Water	Ethylene Glycol Base Antifreeze
Sodium chromate	Chromate	No	Yes	No
Potassium dichromate	Chromate	No	Yes	No
Perry filter elements:				
5020 (type OS)	Chromate	Yes	Yes	No
S-453 (Spin-on)	Chromate	Yes	Yes	No
S-373 (Spin-on)	Nonchromate	Yes	Yes	Yes
5070 (type OS)	Nonchromate	Yes	Yes	Yes
S-473 (Spin-on)	Nonchromate	Yes	Yes	Yes
Lenroc filter element	Nonchromate	Yes	Yes	Yes
Fleetguard filter elements:				
DCA (canister)	Nonchromate	Yes	Yes	Yes
DCA (Spin-on)	Nonchromate	Yes	Yes	Yes
AC filter elements:				
DCA (canister)	Nonchromate	Yes	Yes	Yes
DCA (Spin-on)	Nonchromate	Yes	Yes	Yes
Luber-Finer filter elements:				
LW-4739 (canister)	Nonchromate	Yes	Yes	Yes
LFW-4744 (spin-on)	Nonchromate	Yes	Yes	Yes
Nalcool 2000 (liquid)	Nonchromate	Yes	Yes	Yes
Perry LP-20 (liquid)	Nonchromate	Yes	Yes	Yes
Sy-Cool (liquid)	Nonchromate	Yes	Yes	Yes
Lubercool (liquid)	Nonchromate	Yes	Yes	Yes
DuBois Chemicals IWT-48 (liquid)	Nonchromate	Yes	Yes	Yes
Norman Chemicals C15 (liquid)	Nonchromate	Yes	Yes	Yes
Aqua-Tane (liquid)	Nonchromate	Yes	Yes	Yes

Important: Do not use methoxy propanol base antifreeze in Detroit Diesel engines.

Figure 3. Coolant Inhibitor Chart

ability deters formation of mineral deposits. Inhibitor systems are available in various forms such as coolant filter elements, liquid, and dry bulk inhibitor additives, and as an integral part of permanent antifreeze.

Coolant Filter Elements

Replaceable elements are available with various chemical inhibitor systems. Compatibility of the element with other ingredients of the coolant solution cannot always be taken for granted. Problems have developed from the use of the magnesium lower support plate used by some manufacturer's in their coolant filters. The magnesium plate will be attacked by solutions which will not be detrimental to other metals in the cooling system. The dissolved magnesium will be deposited in the hottest zones of the engine where heat transfer is most critical. The use of an aluminum or zinc support plate in preference to magnesium is recommended to eliminate the potential of this type of deposit.

High-chloride coolants will have a detrimental effect on the water softening capabilities of systems using ion-exchange resins. Accumulations of calcium and magnesium ions removed from the coolant and held captive by the zeolite resin can be released into the coolant by a regenerative process caused by high chloride content solutions.

Bulk Inhibitor Additives

Commercially packaged inhibitor systems are available which can be added directly to the engine coolant or to bulk storage tanks containing coolant solution. Both chromate and nonchromate systems are available and care should be taken regarding inhibitor compatibility with other coolant constituents.

Nonchromate inhibitor systems are recommended for use in Detroit Diesel engines. These systems can be used with either water or permanent-type antifreeze solutions and provide corrosion protection, pH control and water softening. Some nonchromate inhibitor systems offer the additional advantage of a simple on-site test to determine protection level and, since they are added directly to the coolant, require no additional hardware or plumbing.

ANTIFREEZE

When freeze protection is required, a permanent-type antifreeze must be used. An inhibitor system is included in this type of antifreeze and no additional inhibitors are required on initial fill if a minimum antifreeze concentration of 30% by volume is used. Solutions of less than 30% concentration do not provide sufficient corrosion protection. Concentrations over 67% adversely affect freeze protection and heat transfer rates (Fig. 4).

Methoxy propanol base antifreeze is NOT RECOMMENDED for use in Detroit Diesel engines due to the presence of fluoroelastomer (Viton) seals in the cooling system. Before installing ethylene glycol base antifreeze in an engine previously operated with methoxy propanol, the entire cooling system should be drained, flushed with clean water, and examined for rust, scale, contaminants, etc. If deposits are present, the cooling system must be chemically cleaned with a commercial grade heavy-duty descaler.

Ethylene glycol base antifreeze is recommended for use in Detroit Diesel engines. Methyl alcohol antifreeze is NOT recommended because of its effect on the nonmetallic components of the cooling system and because of its low boiling point.

The inhibitors in permanent-type antifreeze should be replenished at approximately 500 hour or 20,000 mile intervals with a nonchromate inhibitor system. Commercially available inhibitor systems (Fig. 2) may be used to reinhibit antifreeze solutions.

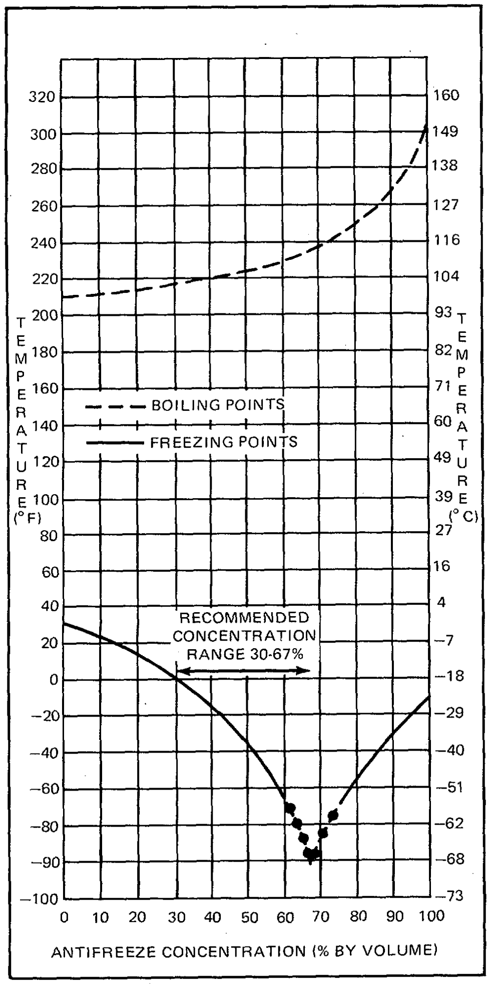


Figure 4. Coolant Freezing and Boiling Temperatures vs. Antifreeze Concentration (Sea Level)

Sealer Additives

Several brands of permanent antifreeze are available with sealer additives. The specific type of sealer varies with the manufacturer. Antifreeze with sealer additives is NOT RECOMMENDED for use in Detroit Diesel engines due to possible plugging throughout various areas of the cooling system.

GENERAL RECOMMENDATIONS

All Detroit Diesel engines incorporate pressurized cooling systems which normally operate at temperatures higher than nonpressurized systems. It is essential that these systems be kept clean and leak-free, that filler caps and pressure relief mechanisms be correctly installed at all times, and that coolant levels be properly maintained.

WARNING

Use extreme care when removing a coolant pressure control cap from an engine. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding) from the hot liquid.

1. Always use a properly inhibited coolant.
2. Do not use soluble oil.
3. Maintain the prescribed inhibitor strength.
4. Always follow the manufacturer's recommendations on inhibitor usage and handling.
5. If freeze protection is required, always use a permanent-type antifreeze.
6. Reinhibit antifreeze with a recommended nonchromate inhibitor system.
7. Do not use a chromate inhibitor with permanent-type antifreeze.
8. Do not use methoxy propanol base antifreeze in Detroit Diesel engines.

9. Do not mix ethylene glycol base antifreeze with methoxy propanol base antifreeze in the cooling system.

10. Do not use an antifreeze containing sealer additives.

11. Do not use methyl alcohol base antifreeze.

12. Use extreme care when removing the coolant pressure control cap.

ENGINE TUNEUP PROCEDURES

There is no scheduled interval for performing an engine tuneup. As long as the engine performance is satisfactory, no tuneup should be needed. Minor adjustments in the valve and injector operating mechanism, governor, etc. should only be required periodically to compensate for normal wear on parts.

To comply with emissions regulations for on-highway vehicle engines; injector timing, exhaust valve clearance, engine idle and no-load speeds, throttle delay or fuel modulator settings must be checked and adjusted, if necessary, at 50,000 mile intervals (refer to *Preventive maintenance*).

The type of governor used depends upon the engine application. Since each governor has different characteristics, the tuneup procedure varies accordingly. The following types of governors are used:

1. Limiting speed mechanical.
2. Variable speed mechanical.
3. Constant speed mechanical.
4. Hydraulic.

The mechanical governors are identified by a name plate attached to the governor housing. The letters D.W.-L.S stamped on the name plate denote a double-weight limiting speed governor. A single-weight variable speed governor name plate is stamped S.W.-V.S.

Normally, when performing a tuneup on an engine in service, it is only necessary to check the various adjustments for a possible change in the settings. However, if a cylinder head, governor, or injectors have been replaced or overhauled, then certain preliminary adjustments are required before the engine is started.

The preliminary adjustments consist of the first four items in the tuneup sequence. The procedures are the same except that the valve clearance is greater for a cold engine.

NOTE

If a supplementary governing device, such as a load limit device, is used, it must be disconnected prior to the tuneup. After the governor and injector rack adjustments are completed, the supplementary governing device must be reconnected and adjusted.

To tuneup an engine completely, perform all of the adjustments in the applicable tuneup sequence given below after the engine has reached normal operating temperature. Since the adjustments are normally made while the engine is stopped, it may be necessary to run the engine between adjustments to maintain normal operating temperature.

Use new valve rocker cover gaskets after the tuneup is completed.

Tuneup Sequence for Mechanical Governor

CAUTION

Before starting an engine after an engine speed-control adjustment or after removal of the engine governor cover, the serviceman must determine that the injector racks move to the no-fuel position when the governor stop lever is placed in the stop position. Engine overspeed will result if the injector racks cannot be positioned at no-fuel with the governor stop lever.

ENGINE TUNEUP

1. Adjust the exhaust valve clearance.
2. Time the fuel injectors.
3. Adjust the governor gap.
4. Position the injector rack control levers.
5. Adjust the maximum no-load speed.
6. Adjust the idle speed.
7. Adjust the buffer screw.
8. Adjust the throttle-booster spring (variable speed governor only).
9. Adjust the supplementary governing device, if used.

EMISSION REGULATIONS FOR ON-HIGHWAY VEHICLE ENGINES

On-highway vehicle and coach engines built by Detroit Diesel Allison are certified to be in compliance with Federal and California Emission Regulations established for each model year beginning with 1970.

Engine certification is dependent on five physical characteristics:

1. Fuel injector type.
2. Maximum full-load engine speed.
3. Camshaft timing.
4. Fuel injector timing.
5. Throttle delay (orifice size). Tables 1 through 6 summarize all of the pertinent data concerning the specific engine configurations required for each model year.

When serviced, all on-highway vehicle and coach engines should comply with the specifications for the specific model year in which the engine was built.

Trucks in a fleet containing engines of various model years can be tuned to the latest model year, provided the engines have been updated to meet the specifications for that particular year.

TABLE 1 (1970-1973 Engines)

Year	1970	1971	1972	1973
Engines	4-53N	4-53N	4-53N	4-53N
Injectors	N40 N45 N50	N40 N45 N50	N40 N45 N50	C40 C45 C50
Maximum Full-load Engine Speed †	2800	2800	2800	2800
Camshaft Timing	Adv.	Adv.	Adv.	Adv.
Injector Timing ‡	1.460 inches	1.460 inches	1.460 inches	1.460 inches
Timing Gage	J 1583	J 1583	J 1583	J 1583
Throttle Delay	No	No	Yes*	Yes*
Yield Link	-	-	-	-

* Throttle delay must have 0.016 inch diameter orifice.
† No-load engine speed will vary with injector size and governor type.
‡ The adjusted height of the fuel injector follower in relation to the injector body.

TABLE 2 (1974-1976 Engines)

Year	1974	1975	1976
Engines	4-53N	4-53N	4-53N
Injectors	C40 C45 C50	C40 C45 C50	C40 C45 C50
Maximum Full-load Engine Speed*	2800	2800	2800
Camshaft Timing	Adv.	Adv.	Adv.
Injector Timing †	1.470 inches	1.470 inches	1.470 inches
Timing Gage	J 24236	J 24236	J 24236
Throttle Delay	Yes‡	Yes‡	Yes‡
Yield Link	Yes	Yes	Yes

* No-Load engine speed will vary with injector size and governor type.
† The adjusted height of the fuel injector follower in relation to the injector body.
‡ 0.250 inch diameter fill hole 0.016 inch diameter discharge orifice.

TABLE 3 (1977 Engines)

Engine	4-53N
(a) Injectors	C40 C45 C50
(a) Maximum Rated Speed	2800
(a) Minimum Rated Speed	2800 (C40) 2400 (C45) 2500 (C50)
Gear Train Timing	Adv.
Injector Timing	1.470 inches
Timing Gage	J 24236
Throttle	(e)
Yield Link	Yes
Setting	0.454 inch
Liner Port Height	0.840 inch
Compression Ratio	21:1
Blower Drive Ratio	2.487:1
Governor Type	Limiting Speed
Thermostat	170-180°F(77-82°C) Nominal Opening Temperature

(a) Not to exceed injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type.

(e) Large fill hole (0.250 inch dia.) 0.016-inch discharge orifice. Use a minimum idle speed at 500 rpm on all engines.

TABLE 4 (1978 Engines)

1978 CALIFORNIA CERTIFIED AUTOMOTIVE CONFIGURATIONS		1978 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS	
Engine Families	4-53TC	Engine Families	4L-53N
Injectors (a)	5A55 5A60	Injectors (a)	C40 C45 C50
APPROVED CONSTANT HORSEPOWER FOR TTAC ENGINES		APPROVED CONSTANT HORSEPOWER FOR TT & TTA ENGINES	
MAXIMUM (b) FULL LOAD SPEED	2500	MAXIMUM FULL LOAD SPEED (b)	2800
MINIMUM FULL LOAD SPEED	2500	MINIMUM FULL LOAD SPEED	2400
CAMSHAFT LOBE POSITION	STD	CAMSHAFT LOBE POSITION	ADV.
INJECTOR TIMING	5A55-1-496 5A60-1-508	INJECTOR TIMING	1.470
THROTTLE DELAY YIELD LINK	Fuel Modulator	THROTTLE DELAY YIELD LINK	(e) REQ
TURBOCHARGER A/R	T04B98 96	TURBOCHARGER A/R	
	3LM353 2.7 sq. in.		

(a) Not to exceed injector size and maximum operating speed that has been established. No-load speed will vary with injector size and governor type.
(b) No-load engine speed will vary with injector size and governor type.
(c) Large fill hole (0.250 inch dia.) 0.016-inch discharge orifice. Use a minimum idle speed of 500 rpm on all engines.

FUEL INJECTOR TIMING GAGE CHART

INJECTOR	TOOL NO.	SETTING	CAM LOB POSITION
5A55	J 9595	1.496	Standard
5A60	J 9595	1.496	Standard
5A60 (Calif. Cert. only)	J 8909	1.508	Standard

TABLE 5. (1979 Engines)

1979 CALIFORNIA ENGINES

FAMILIES	4L-53TC
Injectors	5A55 5A60
Maximum Full-Load Speed	2500
Minimum Full-Load Speed	2500
Minimum Idle Speed	500
Gear Train Timing	Std.
Injector Timing	5A55 – 1.496 5A60 – 1.508
Throttle Delay Setting#	5A55 – .365 5A60 – .404#
Liner Port Height	.84
Liner Part Number	5132803
Turbocharger A/R	T04B98 .96 A/R##
Turbocharger Part Number	5103905##
Blower Drive Ratio	2.49:1
Blower Part Number	5103563-L 5103466-R
Compression Ratio	18.7:1
Exhaust Valve Material	Nimonic 90
Exhaust Valve Part Number	5109925
Certification Label Number	14B7-265

1979 FEDERAL ENGINES

FAMILIES	4L-53T
Injectors	5A55 5A60
Maximum Full-Load Speed	2500
Minimum Full-Load Speed	2500
Minimum Idle Speed	500
Gear Train Timing	Std.
Injector Timing	1.496
Throttle Delay# Setting	.365#
Liner Port Height	.84
Liner Part Number	5132803
Turbocharger A/R	T04B98 .96 A/R##
Turbocharger Part Number	5103905##
Blower Drive Ratio	2.49:1
Blower Part Number	5103563-LH 5103466-RH
Compression Ratio	18.7:1
Exhaust Valve Material	Nimonic 90
Exhaust Valve Part Number	5109925
Certification Label Number	14B7-264

53T Uses fuel modulator.
Optional 3LM-353, 2.7 Sq. in., 5104803.

THROTTLE DELAY AND STARTING AID GAGES

J-24889 For 0.345 inch
J-28779 For 0.365 inch
J-24882 For 0.385 inch
J-28479 For 0.395 inch
J-9509-2 For 0.404 inch
J-23190 For 0.454 inch
J-29062 For 0.504 inch
J-25559 For 0.570 inch
J-26927 For 0.586 & 0.686 inch
J-25560 For 0.636 inch
J-29064 For 0.660 inch
J-29063 For 0.594 inch
J-26645 For 0.160 inch
J-26646 For 0.290 inch

PIN GAGE

J-25558 For 0.069 & 0.072 inch

TIMING GAGES

J-1853 For 1.460 inches
J-26888 For 1.466 inches
J-24236 For 1.470 inches
J-29065 For 1.480 inches
J-1242 For 1.484 inches
J-29066 For 1.490 inches
J-9595 For 1.496 inches
J-25454 For 1.500 inches
J-8909 For 1.508 inches
J-25502 For 1.520 inches

TABLE 6. (1980 Engines)

1980 FEDERAL CERTIFIED AUTOMOTIVE CONFIGURATIONS

ENGINE FAMILIES	4L-53T
Injectors (a)	5A55 5A60
Maximum Full-Load Speed (a)	2500
Minimum Full-Load Speed	2500
Minimum Idle Speed	500
Gear Train Timing	Std.
Injector Timing	1.496
Throttle Delay Setting	(e) .365
Turbocharger A/R	T04B98 .96A/R 3LM-353 2.7 Sq. In.

(a) Refer to Engine Application Rating (Sales Tech Data Book 1, Vol. 3) for specific application usage of injector size and full-load speed combination. No load speed will vary with injector size and governor.

(e) 53T uses fuel modulator.

EXHAUST-VALVE CLEARANCE ADJUSTMENT

The correct exhaust-valve clearance at normal engine operating temperature is important for smooth, efficient operation of the engine.

Insufficient valve clearance can result in loss of compression, misfiring cylinders, and eventually burned valve seats and valve seat inserts. Excessive valve clearance will result in noisy operation, increased valve face wear, and valve lock damage.

Whenever the cylinder head is overhauled, the exhaust valves are reconditioned or replaced, or the valve operating mechanism is replaced or disturbed in any way, the valve clearance must first be adjusted to the cold setting to allow for normal expansion of the engine parts during the engine warm-up period. This will ensure a valve setting that is close enough to the specified clearance to prevent damage to the valves when the engine is started.

All of the exhaust valves may be adjusted in firing order sequence during one full revolution of the crankshaft. Refer to the General specifications at the front of the manual for the engine firing order.

Valve Clearance Adjustment (Cold Engine)

1. Remove the loose dirt from the valve rocker cover and remove the cover.

2. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

3. Rotate the crankshaft, manually or with the starting motor, until the injector follower is fully depressed on the particular cylinder to be adjusted.

CAUTION

If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in the left-hand direction of rotation or the bolt may be loosened.

4. Loosen the exhaust valve, rocker arm, push rod locknut.

5. Place a 0.027-inch feeler gage, J 9708-01, between the end of one exhaust valve stem and the rocker arm bridge (Fig. 1). Adjust the push rod to obtain a smooth pull on the feeler gage.

6. Remove the feeler gage. Hold the push rod with a 5/16-inch wrench and tighten the locknut with a 1/2-inch wrench.

7. Recheck the clearance. At this time, if the adjustment is correct, the 0.025-inch gage will pass freely

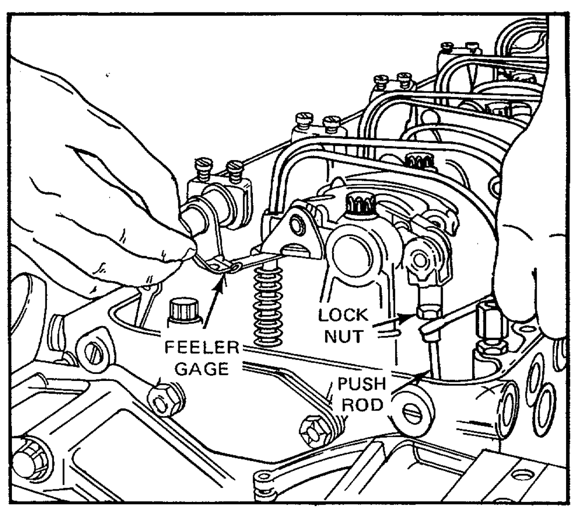


Figure 1. Adjusting Valve Clearance (Four-Valve Head)

between the end of one valve stem and the rocker arm bridge but the 0.027inch gage will not pass through. Readjust the push rod, if necessary.

8. Adjust and check the remaining exhaust valves in the same manner as above.

Valve Clearance Adjustment (Hot Engine)

Maintaining normal engine operating temperature is particularly important when making the final exhaust valve clearance adjustment. If the engine is allowed to cool before setting any of the valves, the clearance, when running at full load, may become insufficient.

1. With the engine at normal operating temperature (refer to Engine Operating Conditions Specifications), recheck the exhaust-valve clearance with feeler gage J 9708-01. At this time, if the valve clearance is correct, the 0.023-inch gage will pass freely between the end of one valve stem and the rocker arm bridge but the 0.025-inch feeler gage will not pass through. Readjust the push rod, if necessary.

2. After the exhaust-valve clearance has been adjusted, check the fuel injector timing (Fuel Injector Timing).

Check Exhaust-Valve Clearance Adjustment

1. With the engine operating at 100°F (38°C) or less, check the valve clearance.

2. If a 0.026-inch feeler gage (J 9708-01) ±0.006 inch will pass between the valve stem and the rocker arm bridge, the valve clearance is satisfactory. If necessary adjust the push rod.

FUEL INJECTOR TIMING

To time an injector properly, the injector follower must be adjusted to a definite height in relation to the injector body.

All of the injectors can be timed in firing order sequence during one full revolution of the crankshaft. Refer to the General Specifications at the front of the manual for the engine firing order.

Time Fuel Injector

After the exhaust-valve clearance has been adjusted (Exhaust-Valve Clearance Adjustment!), time the fuel injectors as follows:

1. Place the governor speed control lever in the idle speed position. If a stop lever is provided, secure it in the stop position.

2. Rotate the crankshaft, manually or with the starting motor, until the exhaust valves are fully depressed on the particular cylinder to be timed.

CAUTION

If a wrench is used on the crankshaft bolt at the front of the engine, do not turn the crankshaft in a left-hand direction of rotation or the bolt may be loosened.

3. Place the small end of the injector timing gage in the hole provided in the top of the injector body with the flat of the gage toward

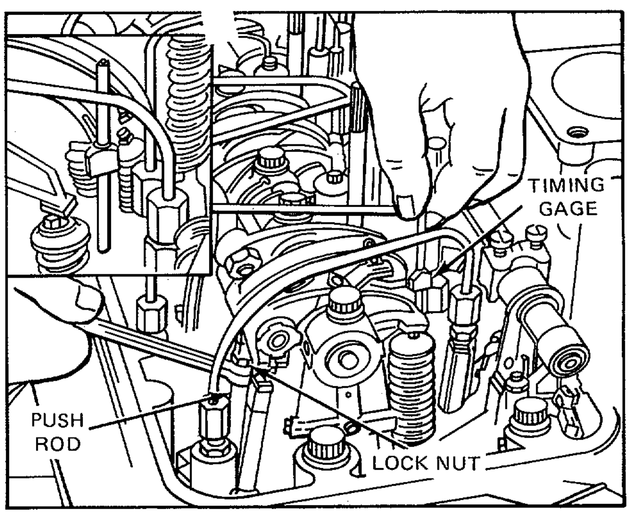


Figure 1 . Timing Fuel Injector

the injector follower (Fig. 1). Refer to Table 1 for the correct timing gage (for vehicle engines, refer to Engine Tuneup).

4. Loosen the injector, rocker arm, push rod locknut.

5. Turn the push rod and adjust the injector rocker arm until the extended part of the gage will just pass over the top of the injector follower.

6. Hold the push rod and tighten the locknut. Check the adjustment and, if necessary, readjust the push rod.

7. Time the remaining injectors in the same manner as outlined above.

8. If no further engine tuneup is required, install the valve rocker cover, using a new gasket.

TABLE 1

Injector	Timing Dimension	Timing Gage	Camshaft Timing	Engine
40	1.484 inches	J 1242	Standard	53
45	1.484 inches	J 1242	Standard	53
S40	1.460 inches	J 1853	Standard	53
S45	1.460 inches	J 1853	Standard	53
N35	1.460 inches	J 1853		
N40	1.460 inches	J 1853	Standard	53N
N45	1.460 inches	J 1853	Standard	53N
N50	1.460 inches	J 1853	Standard	53N

*For automotive applications, refer to Engine Tuneup.

GOVERNOR AND INJECTOR RACK CONTROL ADJUSTMENT

After adjusting the exhaust valves and timing the fuel injectors, adjust the governor (Fig. 1) and the injector rack control levers.

Preliminary Governor Adjustments

1. Clean the governor linkage and lubricate the ball joints and bearing surfaces with clean engine oil.
2. Back out the buffer screw until it projects 9/16 inch from the boss on the control housing.
3. Back out the booster spring eyebolt until it is flush with the outer locknut.

Adjust Variable Speed Spring Tension

1. Adjust the variable speed spring eyebolt until 1/8 inch of the threads project from the outer locknut (Fig. 2).
2. Tighten both locknuts to retain the adjustment.

NOTE

This setting of the eyebolt will produce approximately 7% droop in engine speed from no-load to full load.

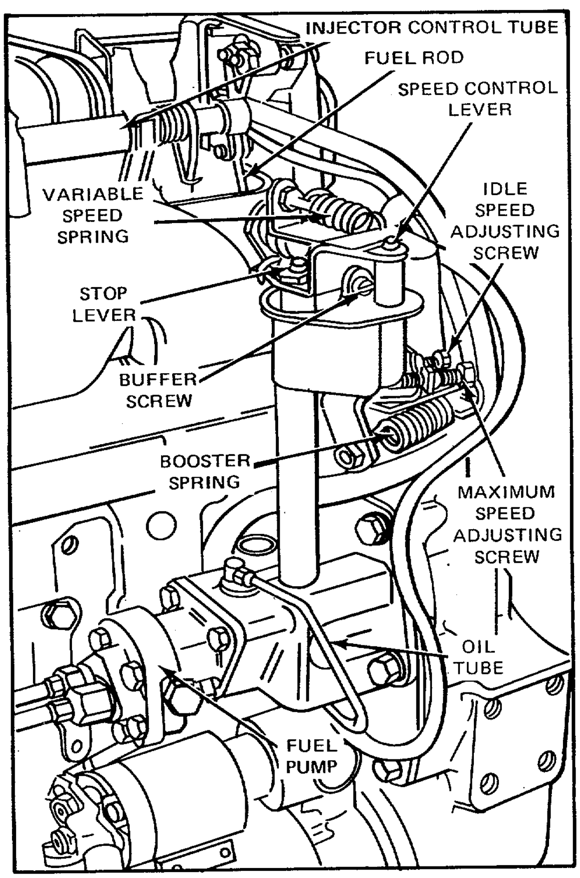


Figure 1. Variable Speed Open Linkage Governor Mounted on Engine

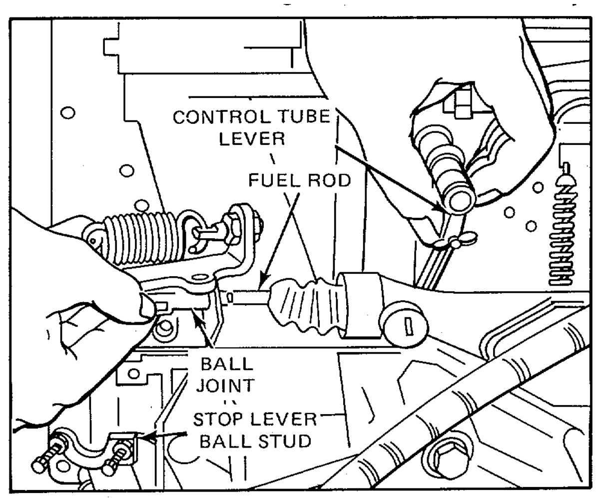


Figure 2. Adjusting Governor Spring Eyebolt

Position Injector Rack Control Levers

The position of the injector control racks must be correctly set in relation to the governor. Their position determines the amount of fuel injected into each cylinder and ensures equal distribution of the load. Adjust the rear injector rack control lever first to establish a guide for adjusting the remaining levers.

1. Remove the valve rocker cover.

2. Disconnect the fuel rod at the stop lever.

3. Loosen all of the inner and outer injector rack control lever adjusting screws. Be sure all of the injector rack control levers are free on the injector control tube.

4. Move the speed control lever to the maximum speed position.

5. Adjust the rear cylinder injector rack control lever adjusting screws (Fig. 3) until both screws are equal in height and-tight on the injector control tube.

6. Move the rear injector control rack into the full-fuel position and note the clearance between the fuel rod and the cylinder headbolt. The clearance should be 1/32 inch or more. If necessary, readjust the injector rack adjusting screws until a clearance of at least 1/32 to 1/16 inch exists. Tighten the adjustment screws.

7. Loosen the nut which locks the ball joint on the fuel rod. Hold the fuel rod in the full-fuel position and adjust the ball joint until it is aligned and will slide on the ball stud on the stop lever (Fig. 4). Position the shutdown cable clip and tighten the fuel rod locknut to retain the adjustment.

8. Check the adjustment by pushing the fuel rod toward the engine and make sure the injector control rack is in the full-fuel position. If necessary, readjust the fuel rod.

9. Manually hold the rear injector rack in the full-fuel position, with the lever on the injector control tube,

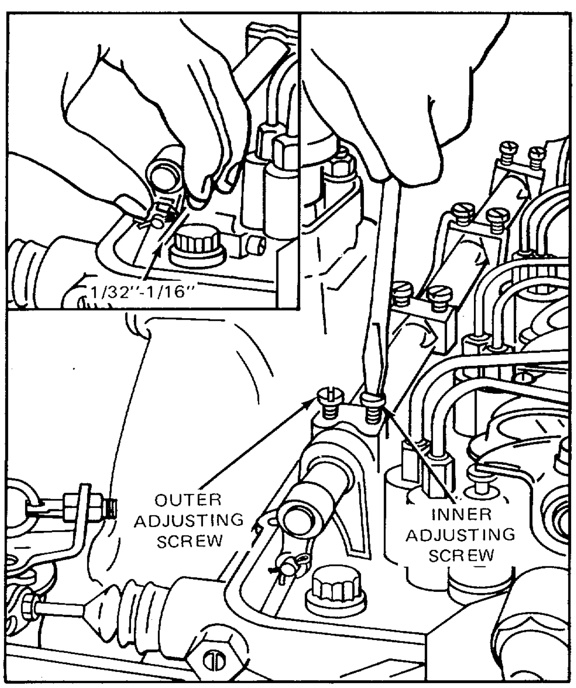


Figure 3. Adjusting Injector Rack Control Lever Adjusting Screws

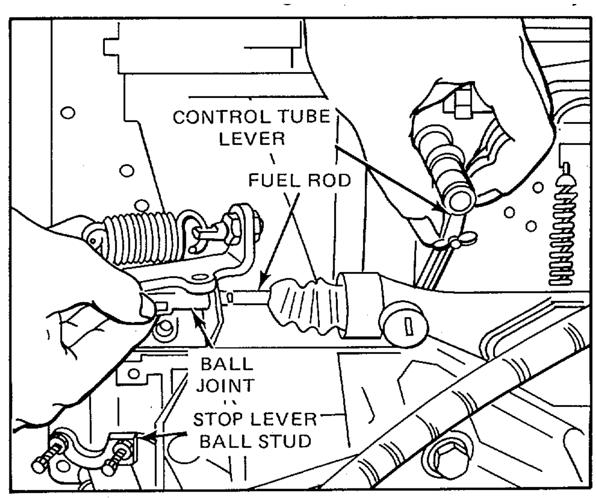


Figure 4. Adjusting Fuel Rod Length

and turn the inner adjusting screw of the adjacent injector rack control lever down until the injector rack moves into the full-fuel position. 'Turn the outer adjusting screw down until it bottoms lightly on the injector control tube. Then alternately tighten both the inner and outer adjusting screws.

CAUTION

Over tightening of the injector rack control lever adjusting screws during installation or adjustment can result in damage to the injector control tube. The recommended torque of the adjusting screws is 24-36 in. lb.

10. Recheck the rear injector rack to be sure that it has remained snug on the ball end of the rack control lever while adjusting the adjacent injector rack. If the rack of the rear injector has become loose, back off the inner adjusting screw slightly on the adjacent injector rack control lever and tighten the outer adjusting screw. When the settings are correct, the racks of both injectors must be snug on the ball end of their respective control levers.

11. Position the remaining injector rack control levers as outlined in Steps 9 and 10.

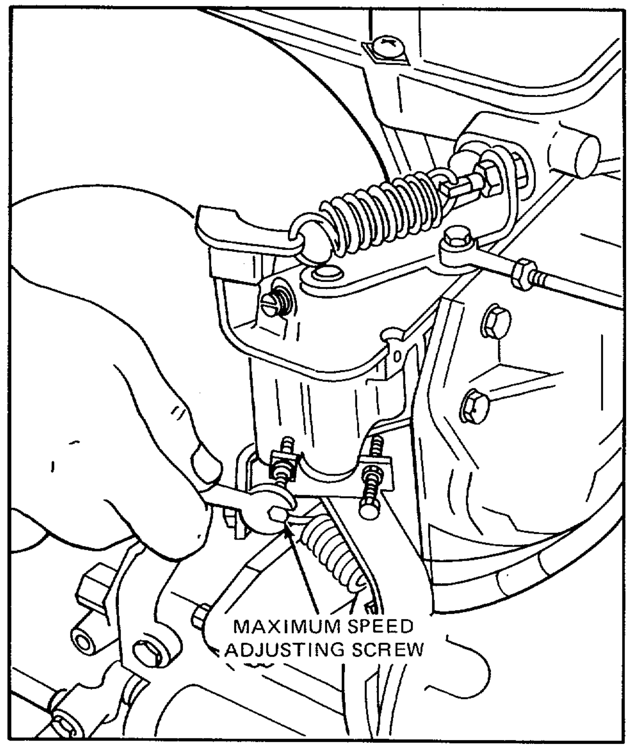


Figure 5. Adjusting Idle Speed

Adjust Engine Idle Speed

1. Make sure the stop lever is in the run position and place the speed control lever in the idle position.

2. With the engine operating, loosen the locknut and turn the idle speed adjusting screw (Fig. 5) in or out until the engine idles at the recommended speed. The recommended idle speed is 550 rpm. However, the idle speed may vary with special engine applications.

3. Hold the idle speed adjusting screw and tighten the locknut.

Adjust Maximum No-Load Speed

1. With the engine running, move the speed control lever to the maximum speed position. Use an accurate tachometer to determine the no-load speed of the engine.

CAUTION

Do not over speed the engine.

2. Loosen the locknut and adjust the maximum speed adjusting screw (Fig. 6) until the required no-load speed is obtained.

3. Hold the adjusting screw and tighten the locknut.

Adjust Buffer Screw

1. With the engine running at idle speed, turn the buffer screw in (Fig. 7) so that it contacts the stop

CAUTION

Do not raise the engine idle speed more than 20 rpm with the buffer screw. Check the maximum no-load speed to make sure it has not increased over 25 rpm by the buffer screw setting.

Adjust Governor Booster Spring

The governor booster spring is used on some engines to reduce the force necessary to move the speed control lever from the idle speed position to the maximum speed position. Adjust the booster spring as follows:

1. Move the speed control lever to the idle speed position.

2. Reduce the tension on the booster spring, if not previously performed, to the minimum by backing off the outer locknut (Fig. 8) until the end of the booster spring eyebolt is flush with the end of the nut.

3. Adjust the eyebolt in the slot in the bracket so that an imaginary line through the booster spring will align with an imaginary centerline through the speed control shaft. Secure the locknuts on the eyebolt to retain the adjustment.

4. Move the speed control lever to the maximum speed position and note the force required. To reduce the force, back off the inner locknut and tighten the outer locknut to increase the tension on the booster spring.

CAUTION

Before tightening the locknuts, reposition the booster spring as in Step 3.

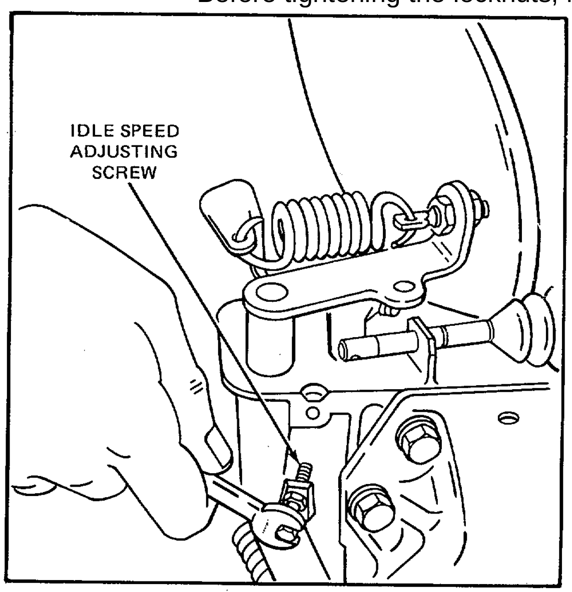


Figure 6. Adjusting Maximum No-Load Engine Speed

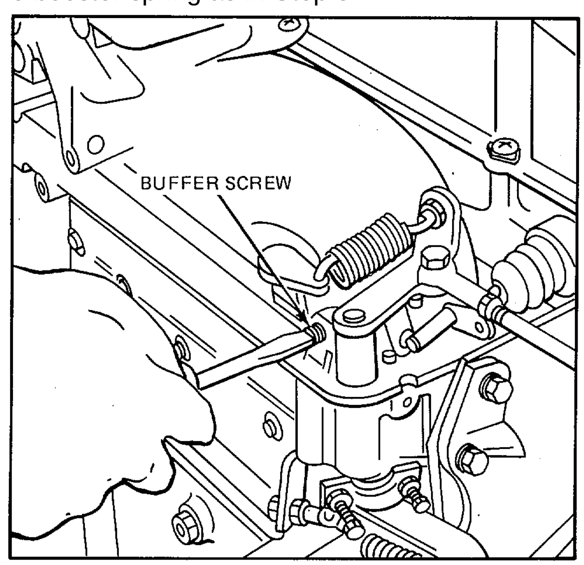
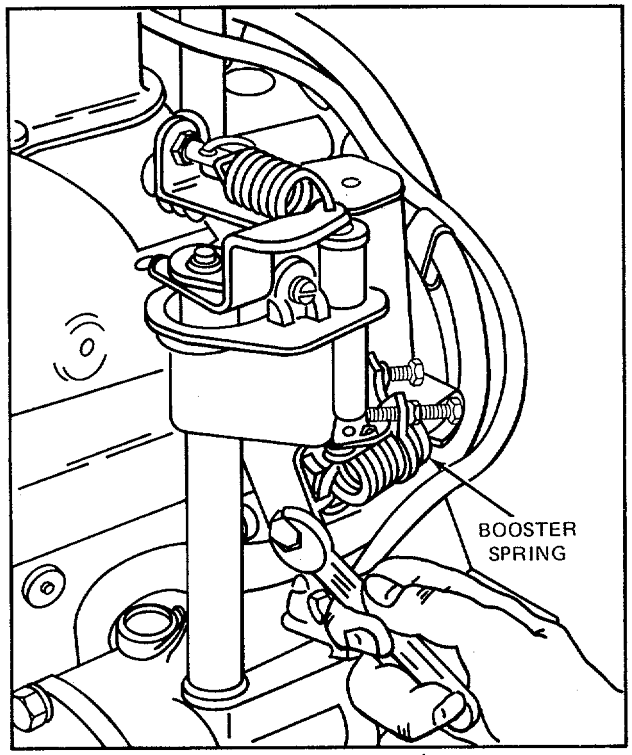


Figure 7. Adjusting Buffer Screw

idle-speed position to the maximum speed position with a constant force, while the engine is running, and when released it will return to the idle speed position.



Adjust Engine Speed Droop

The adjustment of the spring tension as outlined in Adjust Variable Speed Spring Tension will result in approximately 7% droop from the maximum no-load speed to the full-load speed. This is the optimum droop setting for most applications. However, the droop may be changed as necessary for a particular engine application.

1. Lower the speed droop by increasing the spring tension.

2. Raise the speed droop by decreasing the spring tension.

NOTE

A change in the variable speed spring tension will change the engine idle speed and maximum no-load speed, which must also be readjusted. Figure 8. Adjusting Booster Spring

The setting is correct when the speed control lever can be moved from the

ENGINE

LUBRICATION AND PRBEVENTIVE MAINTENANCE

The Lubrication and Preventive Maintenance Schedule is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from a Detroit Diesel engine. The intervals indicated on the chart are time or miles (in thousands) of actual operation.

MAINTENANCE SCHEDULE EXPLANATION

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given in Preparation to Start Engine First Time in chapter II Operations.

ENGINE OVERHAUL

EMISSION CONTROL MAINTENANCE SERVICE CHART (VEHICLE ENGINES)

DAILY	
1. - Lubricating Oil	I
2. - Fuel Tank	I
3. - Fuel Lines	I
4. - Cooling System	I
3000 MILE INTERVALS	
5. - Battery	I
6. - Tachometer Drive	I
4000-6000 MILE INTERVALS	
8. Drive Belts	I
9. Throttle Control	
15,000 MILE INTERVALS	
(2.) - Fuel Tank	I
25,000 MILE INTERVALS	
10. Lubricating Oil Filter	R

6 MONTHS OR I0,000 MILE INTERVALS	MONTHS	6	12	18	24	30	36	42	48	54	60
	MILES (1000)	10	20	30	40	50	60	70	80	90	100
11. - Fuel Filter		R	R	R	R	R	R	R	R	R	R
12. - Coolant Filter		R	R	R	R	R	R	R	R	R	R
13. - Starting Motor		I	I	I	I	I	I	I	I	I	I
(2.) - Fuel Tank			I		I		I		I		I
(4.)Cooling System (hoses)			I		I		I		I		I
14. - Air System			I		I		I		I		I
15. - Exhaust System			I		I		I		I		I
16. - Air Box Drain Tube			I		I		I		I		I
17. - Emergency Shutdown				I			I			I	
18. - Engine (steam clean)			I		I		I		I		I
19. - Radiator			I		I		I		I		I
20. - Shutter Operation			I		I		I		I		I
21. - Oil Pressure			I		I		I		I		I
22. - Governor			I		I		I		I		I
23. - Fuel Injector & Valve Clearance						I					I
24. - Throttle Delay						I					I
25. - Alternator*						I					I

ENGINE OVERHAUL

6 MONTHS OR 1O,O00	MONTHS	6	12	18	24	30	36	42	48	54	60
MILE INTERVALS	MILES (1OOO)	10	20	30	40	50	60	70	80	90	100
26. Engine & Transmission Mounts											
27. Crankcase Pressure							I				
28. Air Box Check Valves							I				I
(1.) Lubricating Oil*											
29. Fan Hub*											
ANNUALLY											
(4.) Cooling System											
30. Thermostats & Seals											
31. Blower Screen											
32. Crankcase Breather											
33. Fan											
AS REQUIRED											
34. Engine Tuneup2|											

I = INSPECT, CORRECT OR REPLACE (IF NECESSARY)
R = REPLACE
* = SEE ITEM

ENGINE OVERHAUL

INDUSTRIAL OFF HIGHWAY AND MARINE	TIME INTERVALS										
HRS. MILES	**DLY**	**8 240**	**50 1,500**	**100 3,000**	**150 4,500**	**200 6,000**	**300 9,000**	**500 15,000**	**700 20,000**	**1,000 30,000**	**2,000 60,000**
1. Lubricating Oil	X				X						
2. Fuel Tank	X							X	X		
3. Fuel Lines	X										
4. Cooling System	X								X	X	
5. Battery				X							
6. Tachometer Drive				X							
7. Air Cleaners		X						X			
8. Drive Belts		X				X					
9. Throttle and Clutch Controls						X				X	
10. Lubricating Oil Filter								X			
11. Fuel Strainer and Filter											
12. Coolant Filter								X			
13. Starting Motor*											
14. Air Systems									X		
15. Exhaust System									X		
16. Air Box Drain Tube										X	
17. Emergency Shutdown									X		
19. Radiator									X		
20. Shutter Operation									X		
21. Oil Pressure									X		
22. Over speed Governor								X			
24. Throttle Delay*											
25. Battery-Charging Alternator							X				
26. Engine and Transmission Mounts											X
27. Crankcase Pressure											X
28. Air Box Check Valves*											
29. Fan Hub									X		
30. Thermostats and Seals									X		
31. Blower Screen										X	
32. Crankcase Breather										X	
34. Engine Tune-up*											

*See Item'

ENGINE OVERHAUL

Item 1 Lubricating Oil

Check the lubricating oil level with the engine stopped. If the engine has just been stopped, wait approximately twenty minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as required to maintain the correct level on the dipstick (refer to Fuel and Oil Specifications).

CAUTION

Oil may be blown out through the crankcase breather if the crankcase is overfilled. Make a visual check for oil leaks around the filters and the external oil lines.

Change the lubricating oil at 12,500 mile intervals (vehicle engines) or 150 hours (4500 mile) intervals (nonvehicle engines). The drain interval may be established on the recommendations of an independent oil analysis laboratory or the oil supplier (based upon the used oil sample analysis) until the most practical oil change period has been determined. Select the proper grade of oil in accordance with the instructions given in the Lubricating Oil Specifications in Fuel and Oil Specifications.

NOTE

If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily.

Item 2 Fuel Tanks

Keep the fuel tank filled to reduce condensation to a minimum. Select the proper grade of fuel in accordance with the Diesel Fuel Oil specifications in Fuel and Oil Specifications. Figure 1. Items 1 and 1O

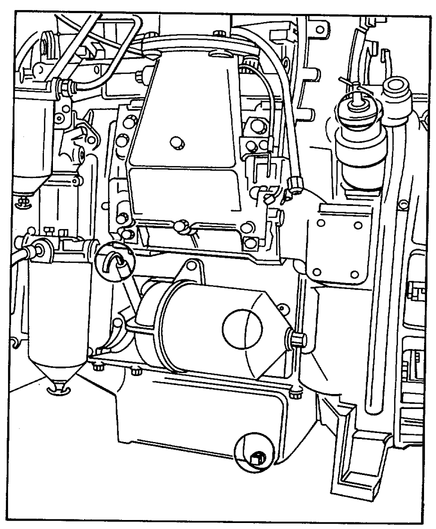


Figure 1. Items 1and 10

Open the drain at the bottom of the fuel tank every 500 hours or 15,000 miles to drain off any water and/or sediment.

Every 12 months or 20,000 miles (700 hours) tighten all fuel tank mountings and brackets. At the same time, check the seal in the fuel tank cap, the breather hole in the cap, and the condition of the crossover fuel line. Repair or replace the parts as necessary.

Diesel Fuel Contamination

The most common form of diesel fuel contamination is water. Water is harmful to fuel systems in itself, but it also promotes the growth of microbiological organisms (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

ENGINE OVERHAUL

Water can be introduced into the fuel supply through poor maintenance (loose or open fuel tank caps), contaminated fuel supply or condensation.

Condensation is particularly prevalent on units which stand idle for extended periods of time, such as marine units. Ambient temperature changes cause condensation in partially filled fuel tanks.

Water accumulation can be controlled by mixing isopropyl alcohol (dry gas) into the fuel oil at a ratio of one pint (.5 liter) per 125 gallons (473 liters) fuel (or 0.10% by volume).

The microbes live in the fuel-water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, nonturbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commercially available biocides. There are two basic types on the market.

The water soluble-type treats only the tank where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.

Diesel fuel soluble-type, suds as Biobor manufactured by U.S. Borax or equivalent, treats the fuel itself and therefore the entire fuel system.

Units going into storage should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

Item 3 Fuel Lines

Make a visual check for fuel leaks at the crossover lines and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

Item 4 Cooling System

Before starting the engine, always check the coolant level. Make sure the coolant covers the radiator tubes. Add coolant as necessary. Do not overfill.

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

Clean the cooling system annually (vehicle engines) or every 1000 hours (30,000 miles nonvehicle engines) using a good radiator cleaning compound 2 in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then fill the system with soft water, adding a good grade of rust inhibitor or a high boiling point-type antifreeze (refer to Engine Coolant in Coolant Specifications). With the use of a proper antifreeze or rust inhibitor, this interval may be lengthened until, normally, this cleaning is done only in the spring or fall. The length of this interval will, however, depend upon an inspection for rust or other deposits on the internal walls of the cooling system. When a thorough cleaning of the cooling system is required, it should be reverse flushed.

Inspect all of the cooling system hoses at least once every 12 months or 20,000 miles (700 hours) to make sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses if necessary.

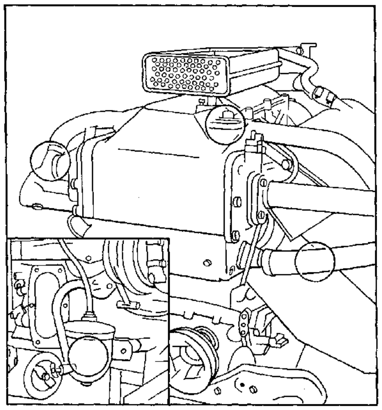


Figure 2. Items 4 and 12

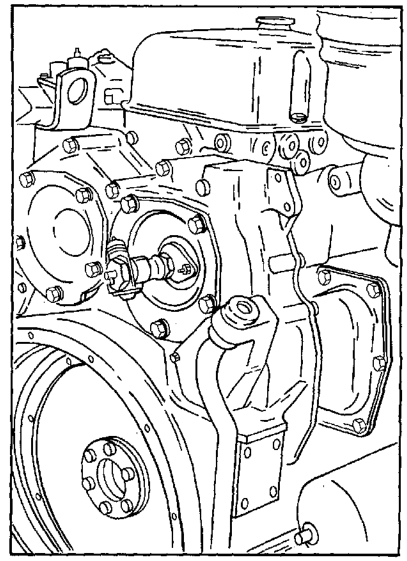


Figure 3. Item 6

Item 5 Battery

Check the specific gravity of the electrolyte in each cell of the battery every 100 hours or 3000 miles. In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. The electrolyte level should be maintained in accordance with the battery manufacturer's recommendations.

Item 6 Tachometer Drive

Lubricate the tachometer drive every 100 hours or 3000 miles with an all purpose grease at the grease fitting. At temperatures above +30°F (-1°C), use a No. 2 grade grease. Use a No. 1 grade grease below this temperature.

Item 7 Air Cleaner

Under no engine operating conditions should the air inlet restriction exceed 25 inches of water (6.2 kPa) for nonturbocharged engines or 20 inches of Figure 3. Item 6 water (5.0 kPa) for turbocharged engines. A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Dry Type

Clean or replace the element in the dry-type Donaldson 'Cyclopac' air cleaner when the restriction indicator instrument indicates high-restriction or when a water manometer reading at the air inlet housing indicates the maximum allowable air inlet restriction (Engine Operating Conditions Specifications).

Item 8 Drive Belts

New drive belts stretch during the first few hours of operation. Run the engine 15 seconds to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, pump drive, battery-charging generator, or alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 240 miles of operation. Thereafter check the tension of the drive belts every 200 hours or 6000 miles and adjust, if necessary. Too tight a belt is destructive to the bearings of the driven part, a loose belt will slip.

Replace all belts in a set when one is worn. Single belts of similar size should not be used as a substitute for a matched belt set; premature belt wear can result because of belt length variation. All belts in a matched belt set are within 0.032 inch of their specified center distances.

Adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 1/2 to 3/4 inch. If belt tension gage BT-33-73FA, or equivalent, is available, adjust the belt tension as outlined in the chart.

NOTE

When installing or adjusting an accessory drive belt(s), be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

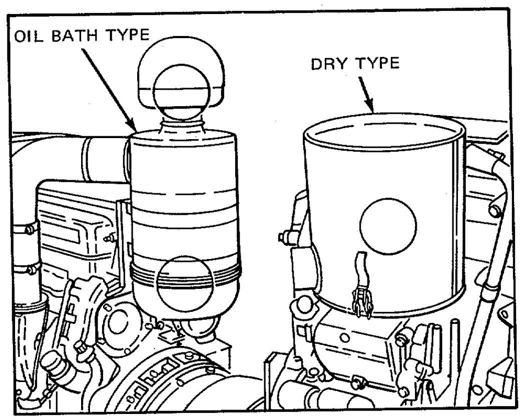


Figure 4. Item 7

Item 9 Throttle Control

Every 200 hours or 6000 miles lubricate the limiting speed governor speed control shaft (in-line 53) through a grease fitting located in the end of the shaft. Use an all purpose grease (No. 2 grade) at temperatures +30°F (-1°C) and above. At temperatures below this use a No. 1 grade grease.

Item 10 Lubricating Oil Filter

Install new oil filter elements and gaskets at a maximum of 25,000 miles (vehicle engines) or 500 hours (nonvehicle engines) or each time the engine oil is changed, whichever comes first. Any deviation, such

BELT TENSION CHART (lbs/belt)

Model	Fan Drive		Alternator/Generator Drive Two		
	2 or 3 belts	Single belt	two 3/8 inch or ½ inch belts	One ½ inch belt	One Wide belt
3, 4-53	40-50		40-50	50-70	40-50
6, 8V-53	60-80	80-100	40-50	50-70	40-50
All	For 3-point or triangular drive use a tension of 90-120.				

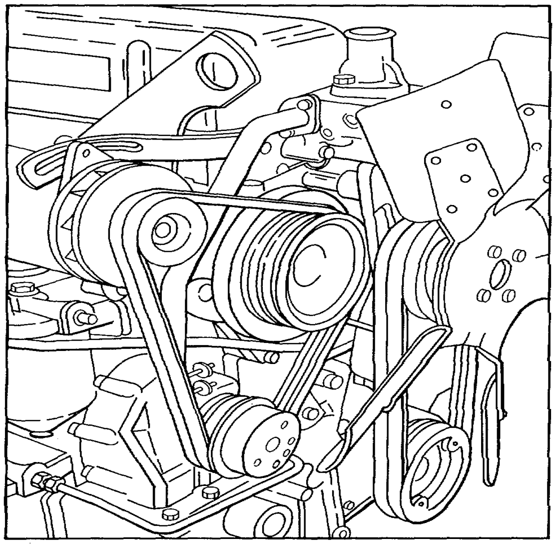


Figure 5. Item 8

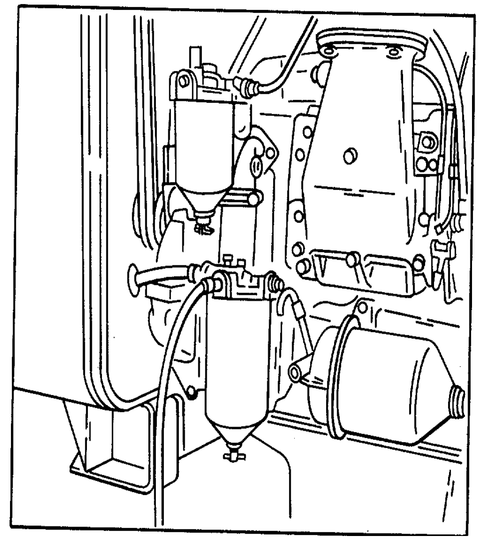


Figure 6. Item 11

as changing filters every other oil change, should be based on a laboratory analysis of the drained oil and the used filter elements to determine if such practice is practical for proper protection of the engine.

Make a visual check of ail lubricating oil lines for wear and chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

When the engine is equipped with a turbocharger, prelubricate it as outlined under *Install Turbocharger* in XXXXXXXXXXXXX or XXXXXXX.

If the engine is equipped with a governor oil filter, change the element every 100 hours or 30,000 miles.

Check for oil leaks after starting the engine.

Item 11 Fuel Filter

Install new elements every 6 months or 10,000 miles (vehicle engines) and 300 hours or 9000 miles (nonvehicle engines) or when plugging is indicated.

A method of determining when elements are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet manifold and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction must not exceed 6 inches of mercury (20.3 kPa). At normal operating speeds, the fuel pressure is 45 to 70 psi (310 to 483 kPa). Change the fuel filter elements whenever the inlet restriction (suction) at the fuel pump reaches 12 inches of mercury (41 kPa) at normal operating speeds and whenever the fuel pressure at the inlet manifold falls to 45 psi (310 kPa).

Item 12 Coolant Filter

If the cooling system is protected by a coolant filter and conditioner, the filter element should be changed every 6 months or 10,000 miles (vehicle engines) and 500 hours or 15,000 miles Figure 6. Item 11

ENGINE OVERHAUL
(nonvehicle engines). Select the proper coolant filter element in accordance with the instructions given in Coolant Specifications. Use a new filter cover gasket when installing the filter element. After replacing the filter and cover gasket, start the engine and check for leaks.

Item 13 Starting Motor

VEHICLE ENGINES
Starting motors which are provided with lubrication fittings (grease cups, hinge cap oilers or oil tubes sealed with pipe plugs) should be lubricated every 6 months or 10,000 miles. Add 8 to 10 drops of oil, of the same grade as used in the engine, to hinge cap oilers; if sealed tubes are provided, remove the pipe plugs, add oil and reseal the tubes. Grease cups should be turned down one turn. Refill the grease cups, if necessary. However, some starting motors do not require lubrication except during overhaul.

NONVEHICLE ENGINES
The electrical starting motor is lubricated at the time of original assembly. Oil can be added to the oil wicks, which project through each bushing and contact the armature shaft, by removing the pipe plugs on the outside of the motor. The wicks should be lubricated whenever the starting motor is taken off the engine or disassembled.

The Sprag overrunning-clutch drive mechanism should be lubricated with a few drops of light engine oil whenever the starting motor is overhauled.

Item 14 Air System

Check all of the connections in the air system to be sure they are tight. Check all hoses for punctures or other damage and replace, if necessary.

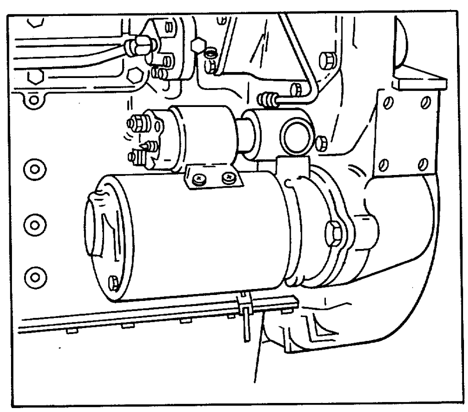


Figure 7. Item 13

Item 15 Exhaust System

Check the exhaust manifold retaining nuts, exhaust flange clamp, and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if one is used.

Item 16 Air Box Drain Tubes

With the engine running, check for flow of air from the air box drain tubes every 18 months or 30,000 miles (1000 hours). If the tubes are clogged, remove, clean, and reinstall the tubes. The air box drain tubes should be cleaned periodically even though a clogged condition is not apparent.

If the engine is equipped with an air box drain tank, drain the sediment periodically.

Item 17 Emergency Shutdown

With the engine running at idle speed, check the operation of the emergency shutdown every 12 months or 20,000 miles. Reset the air shutdown valve in the open position after the check has been made.

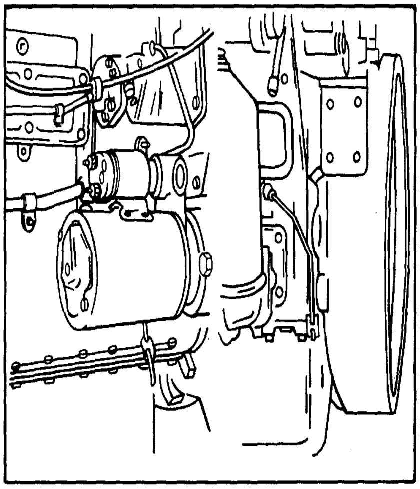


Figure 8. Item 16

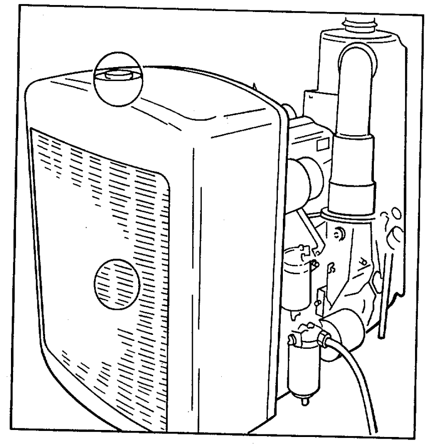


Figure 9. Item 19

Item 18 Engine (Steam Clean)

Steam clean the engine and engine compartment.

CAUTION

Do not apply steam or solvent directly on the battery charging generator/alternator, starting motor or electrical components as damage to electrical equipment may result.

Item 19 Radiator

Inspect the exterior of the radiator core every 12 months or 20,000 miles (700 hours) and, if necessary, clean it with a quality grease solvent such as mineral spirits and dry it with compressed air. DO NOT use fuel oil, kerosene or gasoline. It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Item 20 Shutter Operation

Check the operation of the shutters and clean the linkage and controls.

Item 21 Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the engine is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 700 hours or 20,000 miles.

Item 22 Governor

Check and record the engine idle speed and no-load speed. Adjust as necessary.

An idle speed lower than recommended will cause the engine to be accelerated from a speed lower than the speed at which the engine was certified.

A no-load speed higher than recommended will result in a full-load speed higher than rated and higher than the speed at which the engine was certified.

ENGINE OVERHAUL

Over speed Governor

Lubricate the over speed governor, if it is equipped with a hinge-type cap oiler or oil cup, with 5 or 6 drops of engine oil every 500 hours or 15,000 miles. Avoid excessive lubrication and do not lubricate the governor while the engine is running.

Item 23 Fuel Injectors and Valve Clearance

Check the injector timing and exhaust valve clearance as outlined in Fuel Injector Timing and Exhaust Valve Clearance Adjustment every 50,000 miles. The proper height adjustment between the injector follower and injector body is of primary importance to emission control.

Item 24 Throttle Delay

Inspect and adjust, if necessary, every 30 months or 50,000 miles.

The throttle delay system limits the amount of fuel injected during acceleration by limiting the rate of injector rack movement with a hydraulic cylinder. The initial location of this cylinder must be set with the proper gage to achieve the appropriate time delay.

Inspect the check valve by filling the throttle delay cylinder with diesel fuel and watching for valve leakage while moving the throttle from the idle to the full-fuel position. If more than a drop of fuel oil leaks, replace the check valve.

Item 25 Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

Some alternators have a built-in supply of grease, while others use sealed

bearings. In these latter two cases, additional lubrication is not necessary.

On alternators, the sliprings and brushes can be inspected through the end frame assembly. If the sliprings are dirty, they should be cleaned with 400-grain or finer polishing cloth. Never use emery cloth to clean the sliprings. Hold the polishing cloth against the sliprings with the alternator in operation and blow away all dust after the cleaning operation. If the sliprings are rough or out of round, replace them.

Item 26 Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 36 months or 60,000 miles (2000 hours). Tighten and repair as necessary.

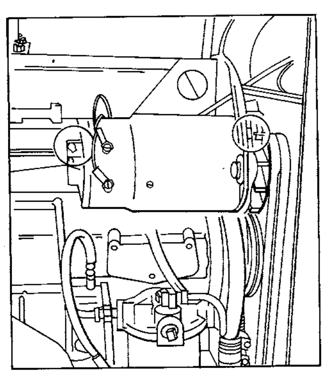


Figure 10. Item 25

ENGINE OVERHAUL
Item 27 Crankcase Pressure

Check and record the crankcase pressure every 36 months or 60,000 miles (2000 hours) (refer to Troubleshooting (Engine)).

Item 28 Air Box Check Valves
Every 100,000 miles or approximately 3000 hours remove the check valves, clean them in solvent and blow out the lines with compressed air. Inspect for leaks after servicing.

Item 29 Fan Hub
If the fan-bearing hub assembly is provided with a grease fitting, use a hand grease gun and lubricate the bearings with one shot of Texaco Premium RB grease, or an equivalent Lithium base multipurpose grease, every 12 months or 20,000 miles (700 hours).

Every 2500 hours or 75,000 miles (vehicle engines) and 4000 hours (nonvehicle engines) clean, inspect and repack the fan-bearing hub assembly with the above recommended grease (refer to Engine Cooling Fan).

At a major engine overhaul, remove and discard the bearings in the fan hub assembly. Pack the hub assembly, using new bearings, with Texaco Premium RB grease, or an equivalent Lithium base multipurpose grease.

Item 30 Thermostats and Seals
Check the thermostats and seals (preferably at the time the cooling system is prepared for winter operation). Replace the seals if necessary.

Item 31 Blower Screen
Inspect the blower screen and gasket assembly annually (vehicle engines) or every 1000 hours or 30,000 miles (nonvehicle engines) and, if necessary, clean the screen in fuel oil and dry it

with compressed air. Install the screen and gasket assembly with the screen side of the assembly toward the blower. Inspect for evidence of blower seal leakage.

Item 32 Crankcase Breather
Remove the externally mounted crankcase breather assembly annually (vehicle engines) or every 1000 hours or 30,000 miles (nonvehicle engines) and wash the steel mesh pad in clean fuel oil. This cleaning period may be reduced or lengthened according to severity of service.

Clean the breather cap, mounted on the valve rocker cover, in clean fuel oil every time the engine oil is changed.

Item 33 Fan
DRIVE BEARING LUBRICATION:
The fan drive bearing should be lubricated as outlined in the chart with a Medium Consistency Silicone Grease (Dow Corning No. 44, or equivalent).

The bearing on current fan assemblies is lubricated through a grease fitting in the drive housing hub. Lubrication

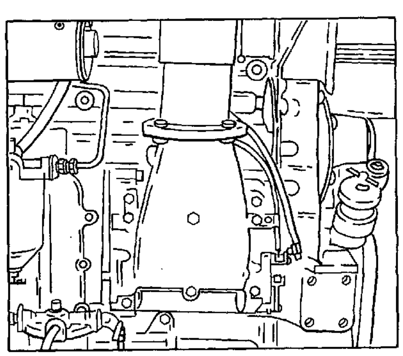


Figure 11. Item 31

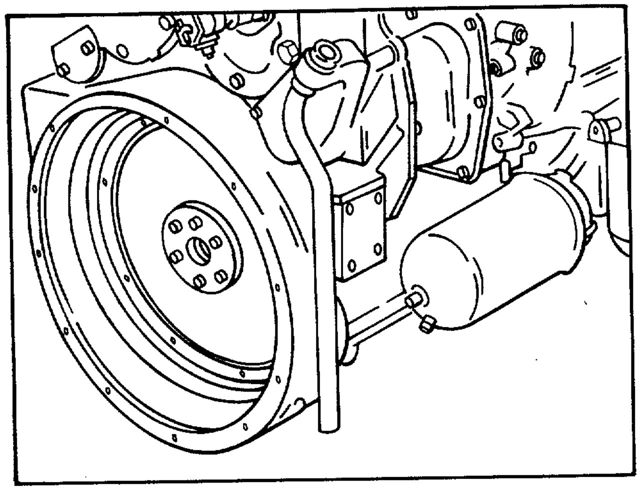


Figure 12. Item 32

of the bearing in former assemblies requires the removal of the fan assembly and partial disassembly. The former assemblies can be updated to include a grease fitting by installing the current housing.

Item 34 Engine Tuneup

There is no scheduled interval for performing a complete engine tuneup. As long as the engine performance is satisfactory, a complete tuneup should not be required. Minor adjustments such as injector timing, exhaust valve clearance, governor, and throttle delay (Items 22, 23, and 24) should be made every 50,000 miles to compensate for normal wear on parts.

TROUBLESHOOTING
ENGINE OPERATION

Certain abnormal conditions which sometimes interfere with satisfactory engine operation, together with methods of determining the cause of such conditions, are covered on the following pages.

Satisfactory engine operation depends primarily on:

1. An adequate supply of air compressed to a sufficiently high compression pressure.

2. The injection of the proper amount of fuel at the right time.

Lack of power, uneven running, excessive vibration, stalling at idle speed, and hard starting may be caused by either low compression, faulty injection in one or more cylinders, or lack of sufficient air.

Since proper compression, fuel injection and the proper amount of air are important to good engine performance, detailed procedures for their investigation are given as follows:

Locating a Misfiring Cylinder

1. Start the engine and run it at part load until it reaches normal operating temperature.

2. Stop the engine and remove the valve-rocker cover(s).

3. Check the valve clearance (refer to Exhaust Valve Clearance Adjustment).

4. Start the engine. Then hold an injector follower down with a screwdriver to prevent operation of the injector. If the cylinder has been misfiring, there will be no noticeable difference in the sound and operation of the engine. If the cylinder has been firing properly, there will be a noticeable difference in the sound and operation when the injector follower is held down. This is similar to short-circuiting a spark plug in a gasoline engine.

5. If the cylinder is firing properly, repeat the procedure on the other cylinders until the faulty one has been located.

6. If the cylinder is misfiring, check the following:
   a. Check the injector timing (refer to Fuel Injector Timing).
   b. Check the compression pressure.
   c. Install a new injector.
   d. If the cylinder still misfires, remove the cam follower (refer to Valve Operating Mechanism) and check for a worn cam roller, camshaft lobe, bent push rod or worn rocker arm bushing.

Checking Compression Pressure

Compression pressure is affected by altitude as shown in Table 1.

Check the compression pressure as follows:

TABLE 1

Minimum Compression Pressure at 600 rpm				Altitude Above Sea Level	
Std. Engine		"N" Engine			
psi	kPa	psi	kPa	Feet	Meters
430	2 963	540	3 721	500	152
400	2 756	500	3 445	2,500	762
370	2 549	465	3 204	5,000	1 524
340	2 343	430	2 963	7,500	2 286
315	2 170	395	2 722	10,000	3 048

ENGINE OVERHAUL

1. Start the engine and run it at approximately one-half rated load until normal operating temperature is reached.

2. Stop the engine and remove the fuel pipes from the injector and fuel connectors of the No. 1 cylinder.

3. Remove the injector and install adaptor J 7915-02 and pressure gage and hose assembly J 6692 (Fig. 1).

4. Use a spare fuel pipe to fabricate a jumper connection between the fuel inlet and return manifold connectors. This will permit fuel from the inlet manifold to flow directly to the return manifold.

5. Start the engine and run it at a 600 rpm. Observe and record the compression pressure indicated on the gage.

NOTE

Do not crank the engine with the starting motor to obtain the compression pressure.

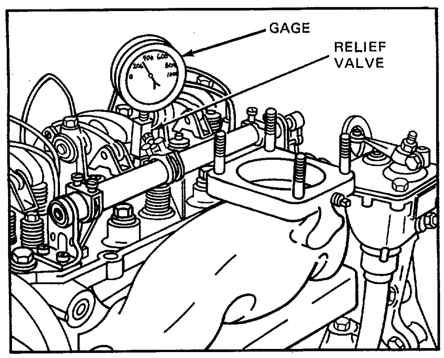


Figure 1. Checking Compression Pressure

6. Perform steps 2 through 5 on each cylinder. The compression pressure in any one cylinder at a given altitude above sea level should not be less than the minimum shown in Table 1. In addition, the variation in compression pressures between cylinders must not exceed 25 psi (172 kPa) at 600 rpm.

EXAMPLE

If the compression pressure readings were as shown in Table 2, it would be evident that No. 3 cylinder should be examined and the cause of the low compression pressure be determined and corrected.

The pressures in Table 2 are for an Engine operating at an altitude near sea level. Note that all of the cylinder pressures are above the low limit for satisfactory engine operation. Nevertheless, the No. 3 cylinder compression pressure indicates that something unusual has occurred and that a localized pressure leak has developed.

Low compression pressure may result from any one of several causes:

A. Piston rings may be stuck or broken. To determine the condition of the rings, remove the air box cover and inspect them by pressing on the rings with a blunt tool. A broken or stuck ring will not have a spring-like action.

TABLE 2

Cylinder	Gage Reading	
	psi	kPa
1	525	3 617
2	520	3 5&3
3	485	3 342
4	515	3 548

B. Compression pressure may be leaking past the cylinder-head gasket, the valve seats, the injector tube or a hole in the piston.

Engine Out of Fuel

The problem in restarting an engine after it has run out of fuel stems from the fact that after the fuel is exhausted from the fuel tank, fuel is then pumped from the primary fuel strainer and sometimes partially removed from the secondary fuel filter before the fuel supply becomes insufficient to sustain engine firing. Consequently, these components must be refilled with fuel and the fuel pipes rid of air in order for the system to provide adequate fuel for the injectors.

When an engine has run out of fuel, there is a definite procedure to follow for restarting it:

1. Fill the fuel tank with the recommended grade of fuel oil. If only partial filling of the tank is possible, add a minimum of ten gallons (38 litres) of fuel.

2. Remove the fuel strainer shell and element from the strainer cover and fill the shell with fuel oil. Install the shell and element.

3. Remove and fill the fuel filter shell and element with fuel oil as in Step 2.

4. Start the engine. Check the filter and strainer for leaks.

NOTE

In some instances, it may be necessary to remove a valve rocker cover and loosen a fuel pipe nut to bleed trapped air from the fuel system. Be sure the fuel pipe is retightened securely before replacing the rocker cover.

Primer J 5956 may be used to prime the entire fuel system. Remove the filler plug in the fuel filter cover and install the primer. Prime the system. Remove the primer and install the filler plug.

Fuel Flow Test

The proper flow of fuel is required for satisfactory engine operation. Check the condition of the fuel pump, fuel strainer and fuel filter as outlined in *Troubleshooting*.

Crankcase Pressure

The crankcase pressure indicates the amount of air passing between the oil control rings and the cylinder liners into the crankcase, most of which is clean air from the air box. A slight pressure in the crankcase is desirable to prevent the entrance of dust. A loss of engine-lubricating oil through the breather tube, crankcase ventilator or dipstick hole in the cylinder block is indicative of excessive crankcase pressure.

The causes of high crankcase pressure may be traced to excessive blow-by due to worn piston rings, a hole or crack in a piston crown, loose piston pin retainers, worn blower oil seals, defective blower, cylinder head or end plate gaskets, or excessive exhaust back pressure. Also, the breather tube or crankcase ventilator should be checked for obstructions.

Check the crankcase pressure with a manometer connected to the oil level dipstick opening in the cylinder block. Check the readings obtained at various engine speeds with the *Engine Operating Conditions Specifications.*

NOTE

The dipstick adaptor must not be below the level of the oil when checking the crankcase pressure.

Exhaust-Back Pressure

A slight pressure in the exhaust system is normal. However, excessive exhaust- back pressure seriously affects engine operation. It may cause an increase in the air box pressure with a resultant loss of efficiency of the blower. This means less air for scavenging which results in poor combustion and higher temperatures.

Causes of high exhaust-back pressure are usually a result of an inadequate or improper type of muffler, an exhaust pipe which is too long or too small in diameter, an excessive number of sharp bends in the exhaust system, or obstructions such as excessive carbon formation or foreign matter in the exhaust system.

Check the exhaust-back pressure, measured in inches of mercury, with a manometer. Connect the manometer to the exhaust manifold (except on turbo- charged engines) by removing the 1/8 inch pipe plug which is provided for that purpose. If no opening is provided, drill an 11/32 inch hole in the exhaust manifold companion flange and tap the hole to accommodate a 1/8 inch pipe plug.

On turbocharged engines, check the exhaust-back pressure in the exhaust piping 6 to 12 inches from the turbine outlet (Fig. 1, *Engine Operating Conditions Specifications*). The tapped hole must be in a comparatively straight pipe area for an accurate measurement.

Check the readings obtained at various speeds (at no-load) with the *Engine Operating Conditions Specifications.*

Air Box Pressure

Proper air box pressure is required to maintain sufficient air for combustion and scavenging of the burned gases. Low air box pressure is caused by a high air inlet restriction, damaged blower rotors, an air leak from the air box (such as leaking end plate gaskets) or a clogged blower air inlet screen. Lack of power or black or grey exhaust smoke are indications of low air box pressure.

High air box pressure can be caused by partially plugged cylinder liner ports.

Check the air box pressure with a manometer connected to an air box drain tube.

Check the readings obtained at various speeds with the *Engine Operating Conditions Specifications*.

Air Inlet Restriction

Excessive restriction of the air inlet will affect the flow of air to the cylinders and result in poor combustion and lack of power. Consequently the restriction must be kept as low as possible considering the size and capacity of the air cleaner. An obstruction in the air inlet system or dirty or damaged air cleaners will result in a high blower inlet restriction.

Check the air inlet restriction with a water manometer connected to a fitting in the air inlet ducting located 2 inches above the air inlet housing (nonturbocharged engines) or the compressor inlet (turbocharged engines). When practicability prevents the insertion of a fitting at this point (nonturbocharged engines), the manometer may be connected to the engine air inlet housing. The restriction at this point should be checked at a specific engine speed. Then the air cleaner and ducting should be removed from the air inlet housing and the engine again operated at the same speed while noting the manometer reading.

The difference between the two readings, with and without the air cleaner and ducting, is the actual restriction caused by the air cleaner and ducting. Check the normal air inlet vacuum at various speeds (at no-load) and compare the results with the *Engine Operating Conditions Specifications*. PROPER USE OF MANOMETER The U-tube manometer is a primary measuring device indicating pressure or vacuum by the difference in the height of two columns of fluid.

Connect the manometer to the source of pressure, vacuum, or differential pressure. When the pressure is imposed, add the number of inches one column of fluid travels up to the amount the other column travels down to obtain the pressure (or vacuum) reading.

The height of a column of mercury is read differently than that of a column of water. Mercury does not wet the inside surface; therefore, the top of the column has a convex meniscus (shape). Water wets the surface and therefore has a concave meniscus. A mercury column is read by sighting horizontally between the top of the convex mercury surface (Fig. 2) and the scale. A water manometer is read by sighting horizontally between the bottom of the concave water surface and the scale.

Should one column of fluid travel further than the other column, due to minor variations in the inside diameter of the tube or to the pressure imposed, the accuracy of the reading obtained is not impaired.

Refer to Table 3 to convert the manometer reading into other units of measurement.

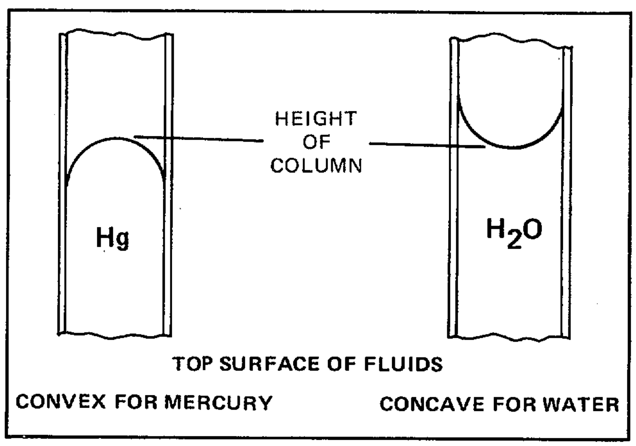


Figure 2. Comparison of Column Height for Mercury and Water Manometers

TABLE 3

PRESSURE CONVERSION CHART

1 inch water	=	0.0735 inches of mercury
1 inch water	=	0.0361 psi
1 inch mercury	=	13.6000 inches of water
1 inch mercury	=	0.4910 psi
1 psi	=	27.7000 inches of water
1 psi	=	2.0360 inches of mercury
1 psi	=	6.895 kPa
1 kPa	=	0.145 psi

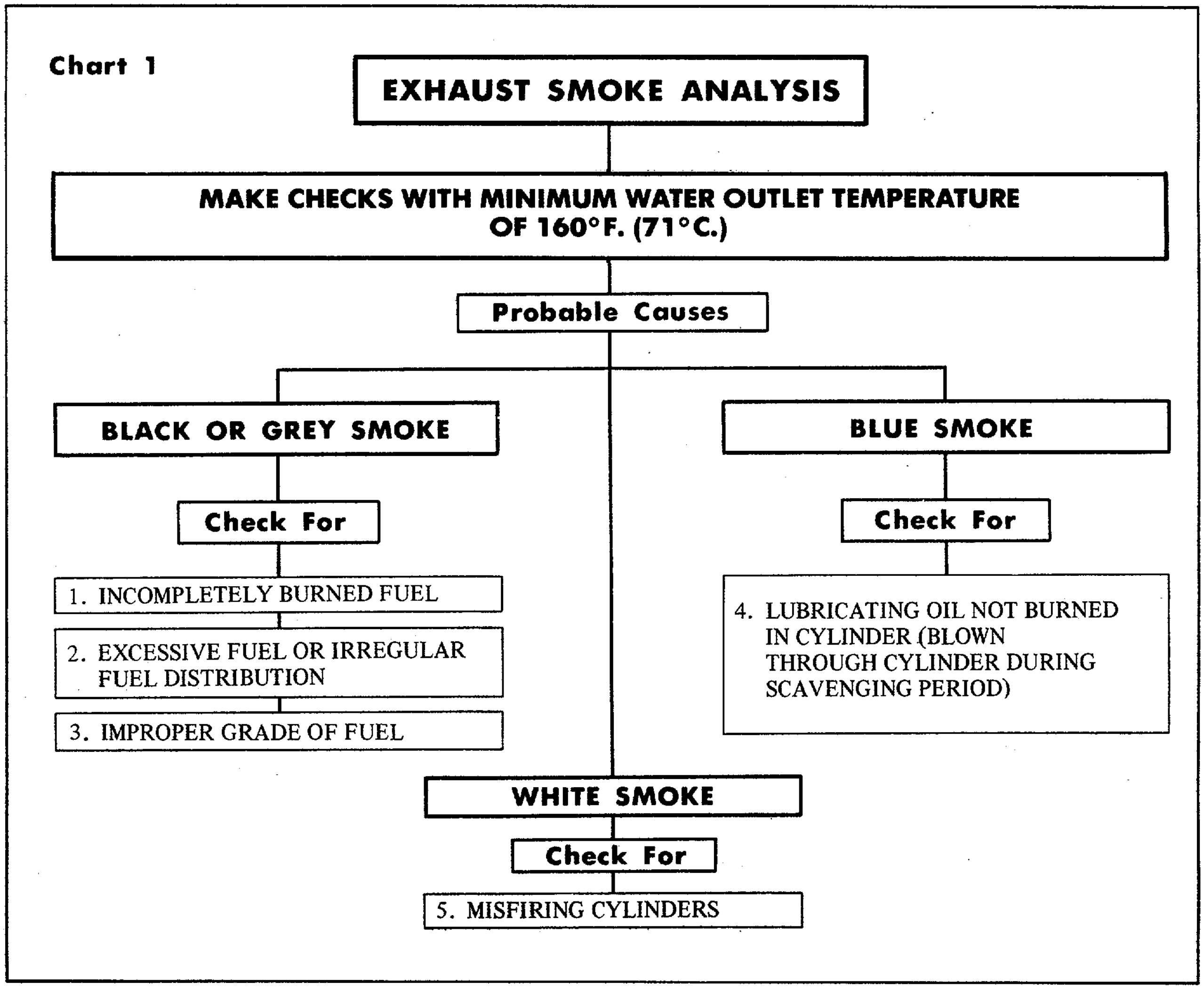


Chart 1
EXHAUST SMOKE ANALYSIS
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F. (71°C.)
Probable Causes
BLACK OR GREY SMOKE
Check For
1. INCOMPLETELY BURNED FUEL
2. EXCESSIVE FUEL OR IRREGULAR FUEL DISTRIBUTION
3. IMPROPER GRADE OF FUEL
BLUE SMOKE
Check For
4. LUBRICATING OIL NOT BURNED IN CYLINDER (BLOWN THROUGH CYLINDER DURING SCAVENGING PERIOD)
WHITE SMOKE
Check For
5. MISFIRING CYLINDERS

Chart 1

EXHAUST SMOKE ANALYSIS

SUGGESTED REMEDY

1. High exhaust-back pressure or a restricted air inlet causes insufficient air for combustion and will result in incompletely burned fuel.

High exhaust-back pressure is caused by faulty exhaust piping or muffler obstruction and is measured at the exhaust manifold outlet with a manometer. Replace faulty parts.

Restricted air inlet to the engine cylinders is caused by clogged cylinder liner ports, air cleaner or blower air inlet screen. Clean these items. Check the emergency stop to make sure that it is completely open and readjust it if necessary.

2. If the engine is equipped with a throttle delay, check for the proper setting, leaky check valve and restricted filling of the piston cavity with oil from the reservoir.

If the engine is equipped with a fuel modulator, check the cam to determine if it is stuck in the full-fuel position. Verify tightness of the roller lever clamp on the control tube. Determine correctness of the installed fuel-modulator piston spring and check if the spring has taken a permanent set, or if the spring rate is too low. Check for improperly timed injectors and improperly positioned injector rack control levers. Time the fuel injectors and perform the appropriate governor tune-up.

Replace faulty injectors if this condition still persists after timing the injectors and performing the engine tune-up.

Avoid lugging the engine as this will cause incomplete combustion.

3. Check for use of an improper grade of fuel. Refer to *Fuel and Oil Specifications*.

4. Check for internal lubricating oil leaks and refer to the *High Lubricating Oil Consumption* chart.

5. Check for faulty injectors and replace as necessary.

Check for low compression and consult the *Hard Starting* chart.

The use of low-cetane fuel will cause this condition. Refer to *Fuel and Oil Specifications.*

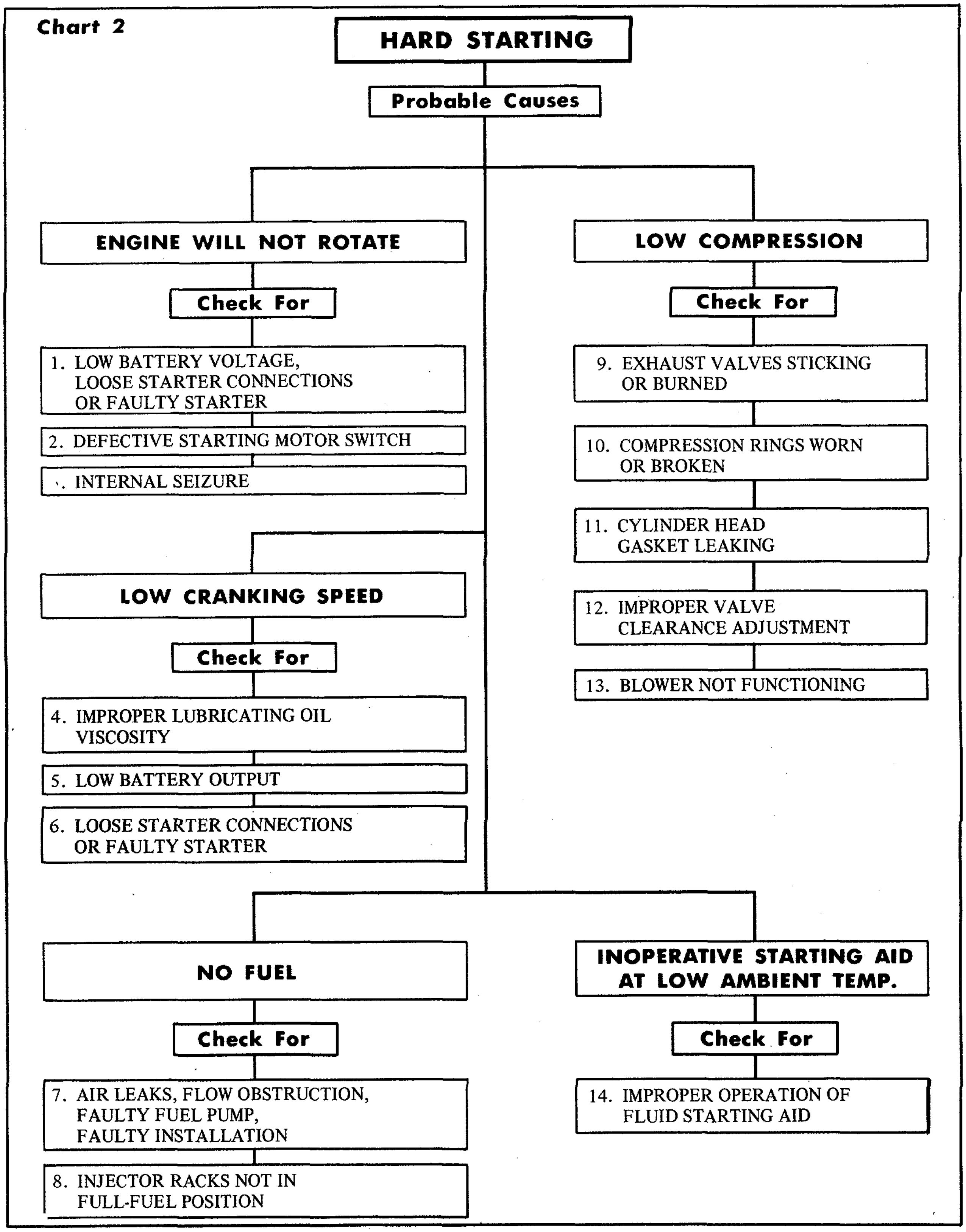


Chart 2
HARD STARTING
Probable Causes
ENGINE WILL NOT ROTATE
Check For
1. LOW BATTERY VOLTAGE, LOOSE STARTER CONNECTIONS OR FAULTY STARTER
2. DEFECTIVE STARTING MOTOR SWITCH
. INTERNAL SEIZURE
LOW CRANKING SPEED
Check For
4. IMPROPER LUBRICATING OIL VISCOSITY
5. LOW BATTERY OUTPUT
6. LOOSE STARTER CONNECTIONS OR FAULTY STARTER
NO FUEL
Check For
7. AIR LEAKS, FLOW OBSTRUCTION, FAULTY FUEL PUMP, FAULTY INSTALLATION
8. INJECTOR RACKS NOT IN FULL-FUEL POSITION
LOW COMPRESSION
Check For
9. EXHAUST VALVES STICKING OR BURNED
10. COMPRESSION RINGS WORN OR BROKEN
11. CYLINDER HEAD GASKET LEAKING
12. IMPROPER VALVE CLEARANCE ADJUSTMENT
13. BLOWER NOT FUNCTIONING
INOPERATIVE STARTING AID AT LOW AMBIENT TEMP.
Check For
14. IMPROPER OPERATION OF FLUID STARTING AID

Chart 2

HARD STARTING

SUGGESTED REMEDY

1. Refer to items 2, 3, and 5 and perform the operations listed.

2. Replace the starting motor switch.

3. Hand crank the engine at least one complete revolution. If the engine cannot be rotated a complete revolution, internal damage is indicated and the engine must be disassembled to ascertain the extent of damage and the cause.

4. Refer to *Lubricating Oil Specifications* in *Fuel and Oil Specifications* for the recommended grade of oil.

5. Recharge the battery if a light load test indicates low or no voltage. Replace the battery if it is damaged or will not hold a charge.

Replace terminals that are damaged or corroded.

At low ambient temperatures, use of a starting aid will keep the battery fully charged by reducing the cranking time.

6. Tighten the starter connections. Inspect the starter commutator and brushes for wear. Replace the brushes if badly worn and overhaul the starting motor if the commutator is damaged.

7. To check for air leaks, flow obstruction, faulty fuel pump or faulty installation, consult the *No Fuel or Insufficient Fuel* chart. Check for bind in the governor-to-injector linkage. Readjust the governor and injector controls if necessary.

9. Remove the cylinder head and recondition the exhaust valves.

10. Remove the air box covers and inspect the compression rings through the ports in the cylinder liners. Overhaul the cylinder assemblies if the rings are badly worn or broken.

11. To check for compression gasket leakage, remove the coolant filler cap and operate the engine. A steady flow of gases from the coolant filler indicates either a cylinder head gasket is damaged or the cylinder head is cracked. Remove the cylinder head and replace the gaskets or cylinder head.

12. Adjust the exhaust valve clearance.

13. Remove the flywheel housing cover at the blower drive support. Then remove the snapring and withdraw the blower drive shaft from the blower. Inspect the blower drive shaft and drive coupling. Replace the damaged parts. Bar the engine over. If the blower does not rotate, remove the air inlet adaptor and visually inspect the blower rotors and end plates. If visual distress is noted, remove the blower (refer to Blower).

14. Operate the starting aid according to the instructions under *Cold Weather Starting Aids*.

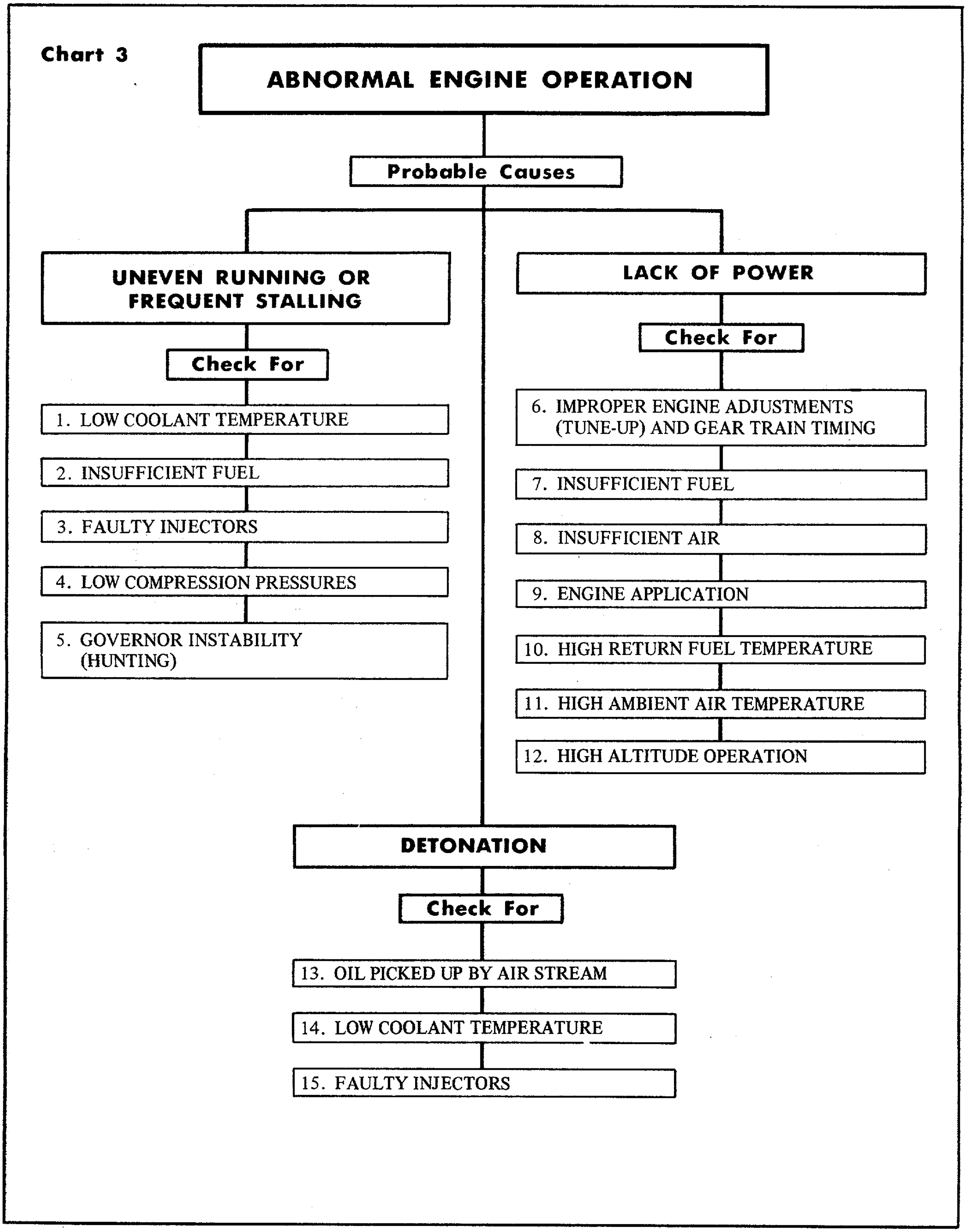


Chart 3
ABNORMAL ENGINE OPERATION
Probable Causes
UNEVEN RUNNING OR FREQUENT STALLING
Check For
1. LOW COOLANT TEMPERATURE
2. INSUFFICIENT FUEL
3. FAULTY INJECTORS
4. LOW COMPRESSION PRESSURES
5. GOVERNOR INSTABILITY (HUNTING)
LACK OF POWER
Check For
6. IMPROPER ENGINE ADJUSTMENTS (TUNE-UP) AND GEAR TRAIN TIMING
7. INSUFFICIENT FUEL
8. INSUFFICIENT AIR
9. ENGINE APPLICATION
10. HIGH RETURN FUEL TEMPERATURE
11. HIGH AMBIENT AIR TEMPERATURE
12. HIGH ALTITUDE OPERATION
DETONATION
Check For
13. OIL PICKED UP BY AIR STREAM
14. LOW COOLANT TEMPERATURE
15. FAULTY INJECTORS

Chart 3

ABNORMAL ENGINE OPERATION

SUGGESTED REMEDY

1. Check the engine coolant temperature gauge and, if the temperature does not reach 160° to 185°F (71° to 85°C) while the engine is operating, consult the *Abnormal Engine Coolant Temperature* chart.

2. Check engine fuel spill back and if the return is less than specified, consult the *No Fuel or Insufficient Fuel* chart.

3. Check the injector timing and the position of the injector racks. If the engine was not tuned correctly, perform an engine tune-up. Erratic engine operation may also be caused by leaking injector spray tips. Replace the faulty injectors.

4. Check the compression pressures within the cylinders and consult the Hard Starting chart if compression pressures are low.

5. Erratic engine operation may be caused by governor-to-injector operating linkage bind or by faulty engine tune-up. Perform the appropriate engine tune-up procedure as outlined for the particular governor used.

6. If the engine is equipped with a throttle delay, check for the proper setting, binding or burrs on the piston or bracket, and a plugged discharge orifice.

If equipped with a fuel modulator, determine if there is any interference with the roller assembly or roller contact with the cam at wide-open-throttle (WOT) position. Check for burrs and binding on the piston and bracket bore. Determine correctness of the installed fuel modulator spring and check if the spring has taken a permanent set, or if the spring rate is too high.

Perform an engine tune-up if performance is not satisfactory.

Check the engine gear train timing. An improperly timed gear train will result in a loss of power due to the valves and injectors being actuated at the wrong time in the engine's operating cycle.

7. Perform a Fuel Flow Test and, if less than the specified fuel is returning to the fuel tank, consult the No Fuel or Insufficient Fuel chart.

8. Check for damaged or dirty air cleaners and clean, repair or replace damaged parts.

Remove the air box covers and inspect the cylinder liner ports. Clean the ports if they are over 50% plugged.

Check for blower air intake obstruction or high exhaust-back pressure. Clean, repair or replace faulty parts.

Check the compression pressures (consult the Hard Starting chart).

9. Incorrect operation of the engine may result in excessive loads on the engine. Operate the engine according to the approved procedures.

10. Refer to Item 13 on Chart 4.

11. Check the ambient air temperature. A power decrease of 0.15 to 0.50 horsepower per cylinder, depending upon injector size, for each 10°F (6°C) temperature rise above 90°F (32°C) will occur. Relocate the engine air intake to provide a cooler source of air.

SUGGESTED REMEDY

12. Engines lose horsepower with increase in altitude. The percentage of power loss is governed by the altitude at which the engine is operating.

13. Fill oil bath air cleaners to the proper level with the same grade and viscosity lubricating oil that is used in the engine.

Clean the air box and drain tubes to prevent accumulations that may be picked up by the air stream and enter the engine's cylinders.

Inspect the blower oil seals by removing the air inlet housing and watching through the blower inlet for oil radiating away from the blower rotor shaft oil seals while the engine is running. If oil is passing through the seals, overhaul the blower.

Check for a defective blower-to-block gasket. Replace the gasket, if necessary.

14. Refer to Item 1 of this chart.

15. Check injector timing and the position of each injector rack. Perform an engine tune-up, if necessary. If the engine is correctly tuned, the erratic operation may be caused by an injector check valve leaking, spray tip holes enlarged or a broken spray tip. Replace faulty injectors.

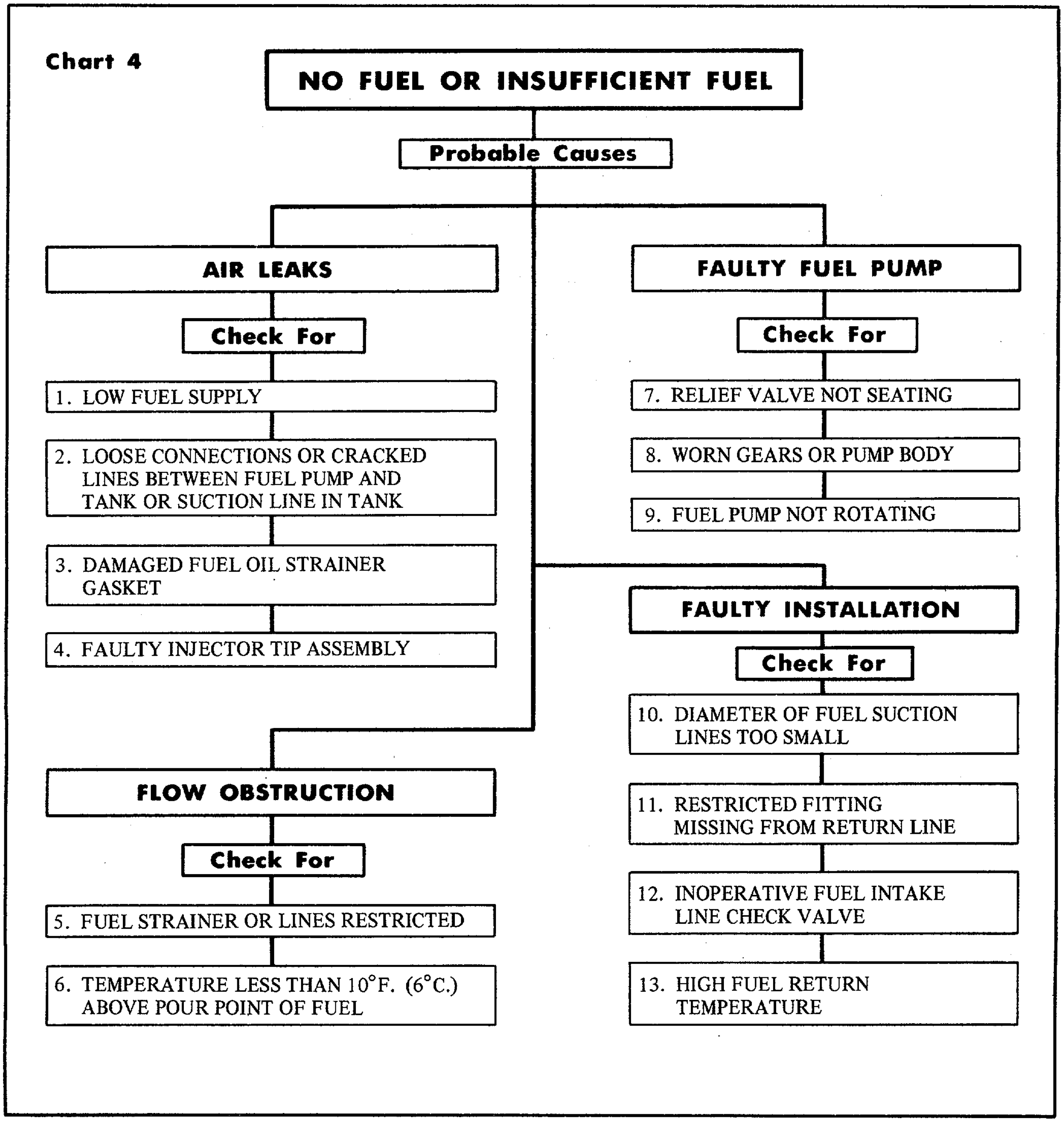


Chart 4
NO FUEL OR INSUFFICIENT FUEL
Probable Causes
AIR LEAKS
Check For
1. LOW FUEL SUPPLY
2. LOOSE CONNECTIONS OR CRACKED LINES BETWEEN FUEL PUMP AND TANK OR SUCTION LINE IN TANK
3. DAMAGED FUEL OIL STRAINER GASKET
4. FAULTY INJECTOR TIP ASSEMBLY
FLOW OBSTRUCTION
Check For
5. FUEL STRAINER OR LINES RESTRICTED
6. TEMPERATURE LESS THAN 10°F. (6°C.) ABOVE POUR POINT OF FUEL
FAULTY FUEL PUMP
Check For
7. RELIEF VALVE NOT SEATING
8. WORN GEARS OR PUMP BODY
9. FUEL PUMP NOT ROTATING
FAULTY INSTALLATION
Check For
10. DIAMETER OF FUEL SUCTION LINES TOO SMALL
11. RESTRICTED FITTING MISSING FROM RETURN LINE
12. INOPERATIVE FUEL INTAKE LINE CHECK VALVE
13. HIGH FUEL RETURN TEMPERATURE

Chart 4

NO FUEL OR INSUFFICIENT FUEL

SUGGESTED REMEDY

1. The fuel tank should be filled above the level of the fuel suction tube.

2. Perform a *Fuel Flow Test* and, if air is present, tighten loose connections and replace cracked lines.

3. Perform a *Fuel Flow Test* and, if air is present, replace the fuel strainer gasket when changing the strainer element.

4. Perform a *Fuel Flow Test* and, if air is present with all fuel lines and connections assembled correctly, check for and replace faulty injectors.

5. Perform a *Fuel Flow Test* and re- place the fuel strainer and filter elements and the fuel lines, if necessary.

6. Refer to *Fuel and Oil Specifications* for the recommended grade of fuel.

7. Perform a *Fuel Flow Test* and, if inadequate, clean and inspect the valve seat assembly.

8. Replace the gear and shaft assembly or the pump body.

9. Check the condition of the fuel pump drive and blower drive and replace defective parts.

10. Replace with larger tank-to-engine fuel lines.

11. Install a restricted fitting in the return line.

12. Make sure that the check valve is installed in the line correctly; the arrow should be on top of the valve assembly or pointing upward. Reposition the valve if necessary. If the valve is inoperative, replace it with a new valve assembly.

13. Check the engine fuel spill-back temperature. The return fuel temperature must be less than 150°F (66°C) or a loss in horsepower will occur. This condition may be corrected by installing larger fuel lines or relocating the fuel tank to a cooler position.

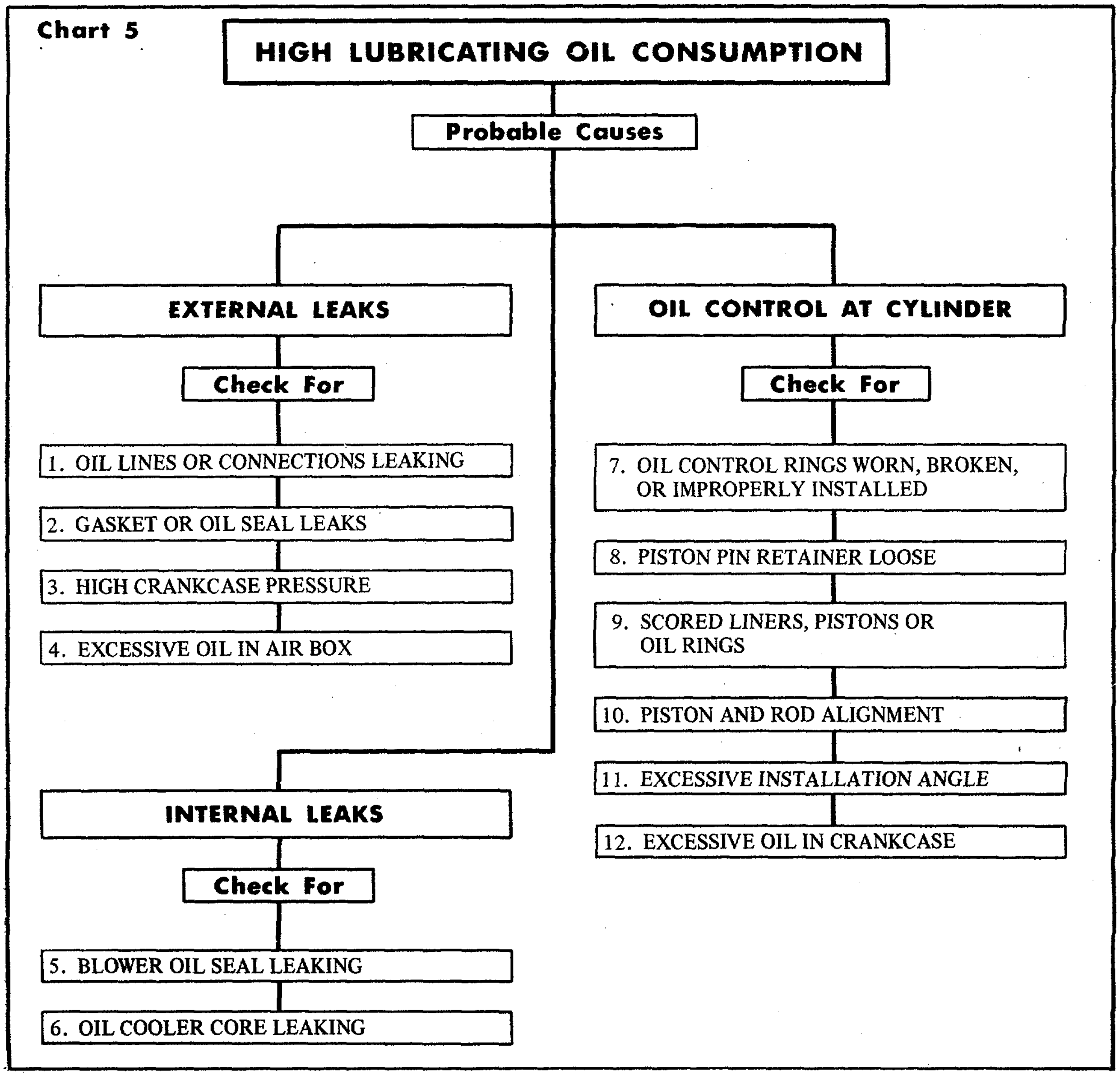


Chart 5
HIGH LUBRICATING OIL CONSUMPTION
Probable Causes
EXTERNAL LEAKS
Check For
1. OIL LINES OR CONNECTIONS LEAKING
2. GASKET OR OIL SEAL LEAKS
3. HIGH CRANKCASE PRESSURE
4. EXCESSIVE OIL IN AIR BOX
INTERNAL LEAKS
Check For
5. BLOWER OIL SEAL LEAKING
6. OIL COOLER CORE LEAKING
OIL CONTROL AT CYLINDER
Check For
7. OIL CONTROL RINGS WORN, BROKEN, OR IMPROPERLY INSTALLED
8. PISTON PIN RETAINER LOOSE
9. SCORED LINERS, PISTONS OR OIL RINGS
10. PISTON AND ROD ALIGNMENT
11. EXCESSIVE INSTALLATION ANGLE
12. EXCESSIVE OIL IN CRANKCASE

Chart 5

SUGGESTED REMEDY

1. Tighten connections or replace defective parts.

2. Replace defective gaskets or oil seals.

3. Refer to the *Excessive Crankcase Pressure* chart.

4. Refer to the *Abnormal Engine Operation* chart.

5. Remove the air inlet housing and inspect the blower end plates while the engine is operating. If oil is seen on the end plate radiating away from the oil seal, overhaul the blower.

6. Inspect the engine coolant for lubricating oil contamination; if contaminated, replace the oil cooler core. Then use a good grade of cooling system cleaner to remove the oil from the cooling system.

7. Replace the oil control rings.

8. Replace the piston pin retainer and defective parts.

9. Remove and replace the defective parts.

10. Check the crankshaft thrust washers for wear. Replace worn and defective parts.

11. Decrease the installation angle.

12. Fill the crankcase to the proper level only.

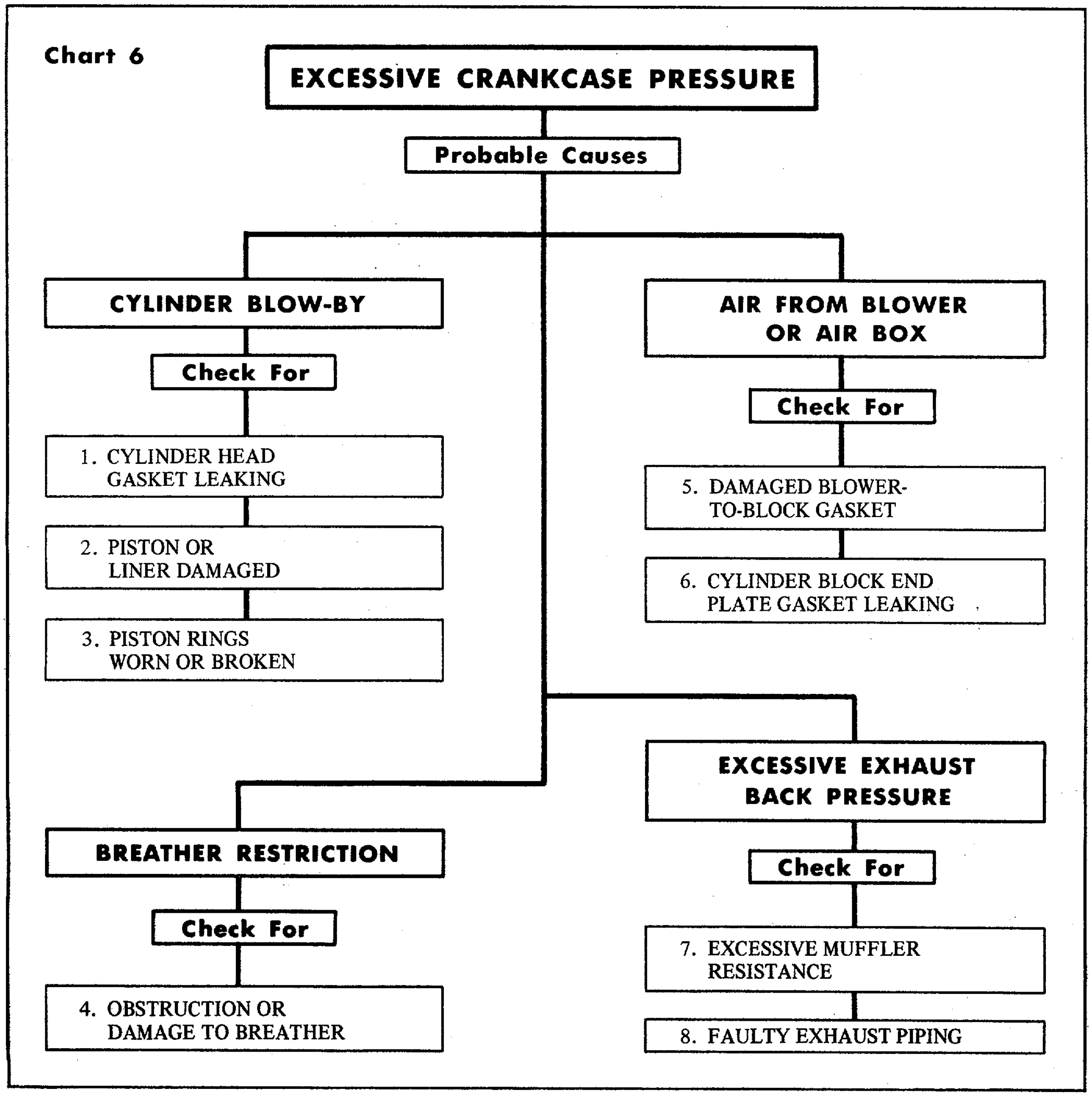


Chart 6
EXCESSIVE CRANKCASE PRESSURE
Probable Causes
CYLINDER BLOW-BY
Check For
1. CYLINDER HEAD GASKET LEAKING
2. PISTON OR LINER DAMAGED
3. PISTON RINGS WORN OR BROKEN
AIR FROM BLOWER OR AIR BOX
Check For
5. DAMAGED BLOWER-TO-BLOCK GASKET
6. CYLINDER BLOCK END PLATE GASKET LEAKING
BREATHER RESTRICTION
Check For
4. OBSTRUCTION OR DAMAGE TO BREATHER
EXCESSIVE EXHAUST BACK PRESSURE
Check For
7. EXCESSIVE MUFFLER RESISTANCE
8. FAULTY EXHAUST PIPING

Chart 6

SUGGESTED REMEDY

1. Check the compression pressure and, if only one cylinder has low compression, remove the cylinder head and replace the head gaskets.

2. Inspect the piston and liner and replace damaged parts.

3. Install new piston rings.

4. Clean and repair or replace the breather assembly.

5. Replace the blower-to-block gasket.

6. Replace the end plate gasket.

7. Check the exhaust-back pressure and repair or replace the muffler if an obstruction is found.

8. Check the exhaust-back pressure and install larger piping if it is determined that the piping is too small, too long, or has too many bends.

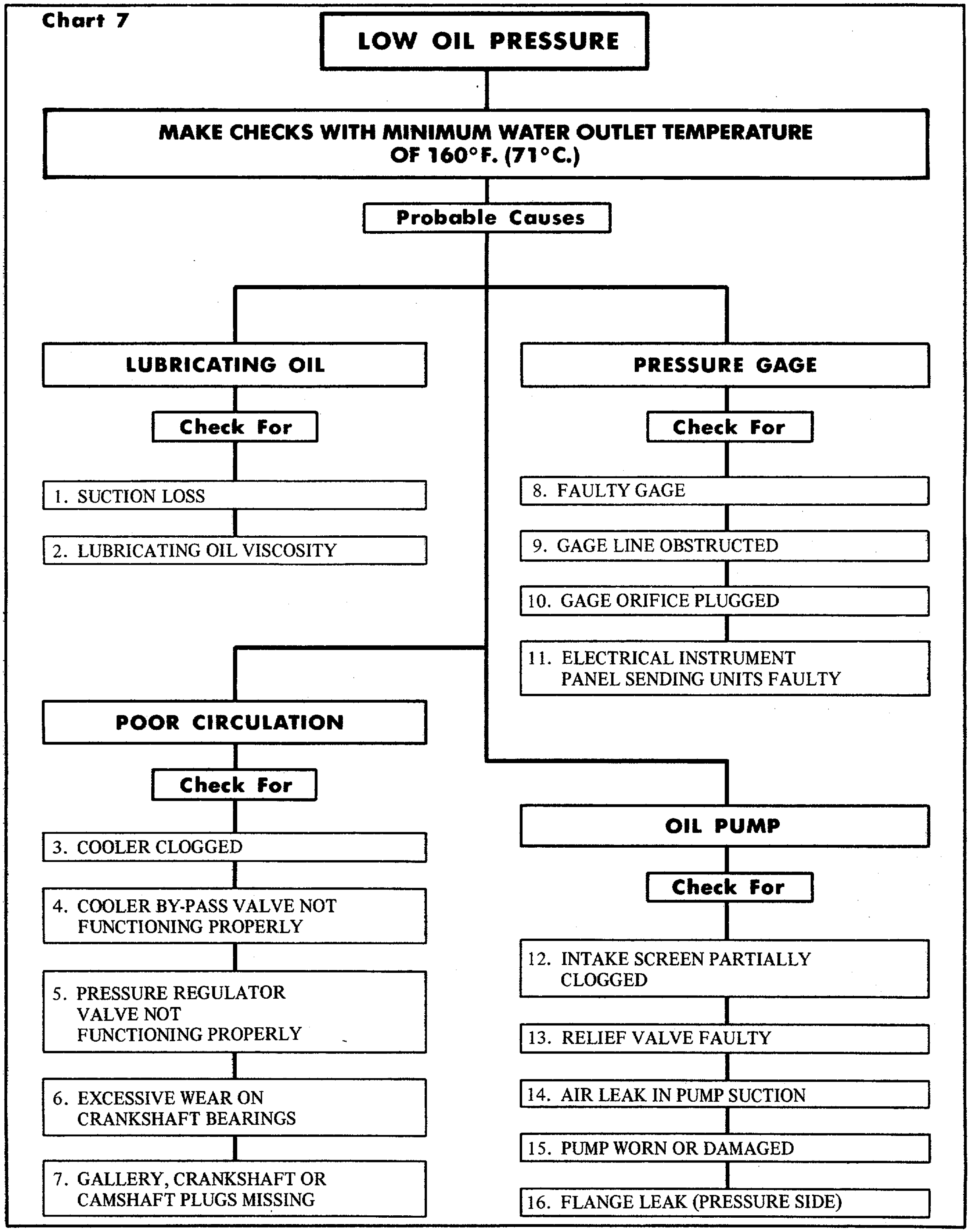


Chart 7
LOW OIL PRESSURE
MAKE CHECKS WITH MINIMUM WATER OUTLET TEMPERATURE OF 160°F. (71°C.)
Probable Causes
LUBRICATING OIL
Check For
1. SUCTION LOSS
2. LUBRICATING OIL VISCOSITY
PRESSURE GAGE
Check For
8. FAULTY GAGE
9. GAGE LINE OBSTRUCTED
10. GAGE ORIFICE PLUGGED
11. ELECTRICAL INSTRUMENT PANEL SENDING UNITS FAULTY
POOR CIRCULATION
Check For
3. COOLER CLOGGED
4. COOLER BY-PASS VALVE NOT FUNCTIONING PROPERLY
5. PRESSURE REGULATOR VALVE NOT FUNCTIONING PROPERLY
6. EXCESSIVE WEAR ON CRANKSHAFT BEARINGS
7. GALLERY, CRANKSHAFT OR CAMSHAFT PLUGS MISSING
OIL PUMP
Check For
12. INTAKE SCREEN PARTIALLY CLOGGED
13. RELIEF VALVE FAULTY
14. AIR LEAK IN PUMP SUCTION
15. PUMP WORN OR DAMAGED
16. FLANGE LEAK (PRESSURE SIDE)

Chart 7

LOW OIL PRESSURE

SUGGESTED REMEDY

1. Check the oil and bring it to the proper level on the dipstick or correct the installation angle.

2. Consult the *Lubrication Oil Specifications in Fuel and Oil Specifications* for the recommended grade and viscosity of oil.

Check for fuel leaks at the injector nut seal ring and fuel pipe connections. Leaks at these points will cause lubricating oil dilution. Refer to *Fuel Leak Detection*.

3. A plugged oil cooler is indicated by excessively high lubricating oil temperature. Remove and clean the oil cooler core.

4. Remove the bypass valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

5. Remove the pressure regulator valve and clean the valve and valve seat and inspect the valve spring. Replace defective parts.

6. Change the bearings. Consult the *Lubricating Oil Specifications in Fuel and Oil Specifications* for the proper grade and viscosity of oil. Change the oil filters.

7. Replace missing plugs.

8. Check the oil pressure with a reliable gauge and replace the gauge if found faulty.

9. Remove and clean the gauge line; replace it, if necessary.

10. Remove and clean the gauge orifice.

11. Repair or replace defective electrical equipment.

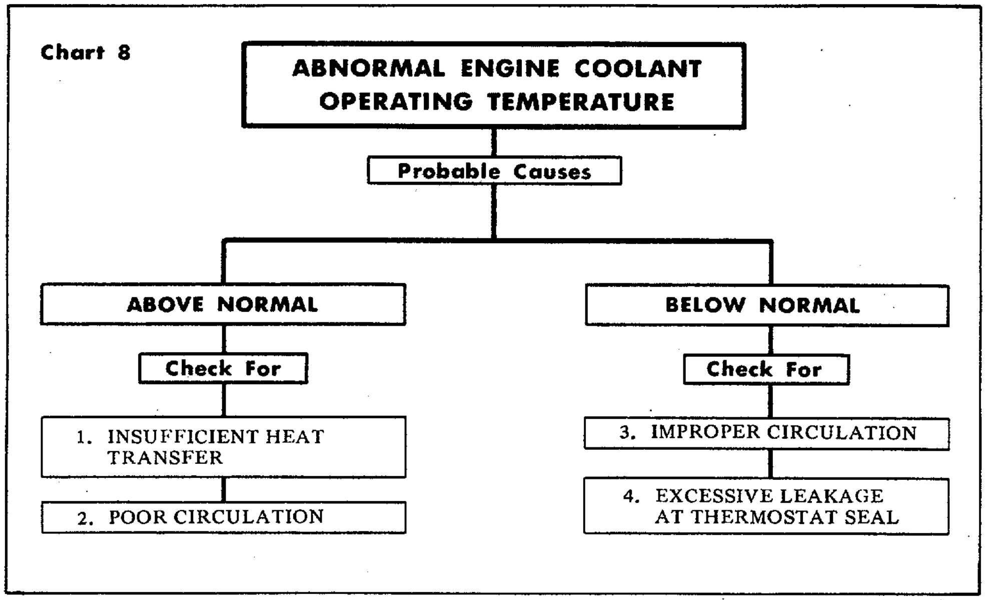
12. Remove and clean the oil pan and oil intake screen. Consult the *Lubricating Oil Specifications in Fuel and Oil Specifications* for the proper grade and viscosity of oil. Change the oil filters.

13. Remove and inspect the valve, valve bore, and spring. Replace faulty parts.

14. Disassemble the piping and install new gaskets.

15. Remove the pump. Clean and replace defective parts.

16. Remove the flange and replace the gasket.



SUGGESTED REMEDY

1. Clean the cooling system with a good cooling system cleaner and thoroughly flush to remove scale deposits. Clean the exterior of the radiator core to open plugged passages and permit normal air flow. Adjust fan belts to the proper tension to prevent slippage. Check for an improper size radiator or inadequate shrouding. Repair or replace inoperative tempera- ture-controlled fan or inoperative shutters.

2. Check the coolant level and fill to the filler neck if the coolant level is low. Inspect for collapsed or disintegrated hoses. Replace faulty hoses. Thermostat may be inoperative. Remove, inspect, and test the thermostat; replace if found faulty. Check the water pump for a loose or damaged impeller. Check the flow of coolant through the radiator. A clogged radiator will cause an inadequate supply of coolant on the suction side of the pump. Clean the radiator core. Remove the coolant filler cap and operate the engine, checking for combustion gases in the cooling system. The cylinder head must be removed and inspected for cracks and the head gaskets re- placed if combustion gases are entering the cooling system. Check for an air leak on the suction side of the water pump. Replace defective parts.

3. The thermostat may not be closing. Remove, inspect and test the thermostat. Install a new thermostat, if necessary.

Check for an improperly installed heater.

4. Excessive leakage of coolant past the thermostat seal(s) is a cause of continued low coolant operating temperature. When this occurs, replace the thermostat seal(s).

STORAGE

PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission, and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below.

It will be necessary to remove all rust or corrosion completely from any ex- posed part before applying a rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.

The engine should be stored in a building which is dry and can be heated during the winter months. Moisture-absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

TEMPORARY STORAGE (30 days or less)

To protect an engine for a temporary period of time, proceed as follows:

1. Drain the engine crankcase.

2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil.

3. Fill the fuel tank with the recommended grade of fuel oil. Operate the engine for two minutes at 1200 rpm and no load.

NOTE

Do not drain the fuel system or the crankcase after this run.

4. If freezing weather is expected -during the storage period, add a permanent type antifreeze solution in accordance with the manufacturer's recommendations. Drain the raw water system and leave the draincocks open.

5. Clean the entire exterior of the engine (except the electrical system) with fuel oil and dry it with compressed air.

6. Seal all of the engine openings. The material used for this purpose must be waterproof, vaporproof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

An engine prepared in this manner can be returned to service in a short time by removing the seals at the engine openings, checking the engine coolant, fuel oil, lubricating oil, transmission, and priming the raw water pump, if used.

EXTENDED STORAGE (more than 30 days)

When an engine is to be removed from operation for an extended period of time, prepare it as follows:

1. Drain and thoroughly flush the cooling system with clean, soft water.

2. Refill the cooling system with clean, soft water.

3. Add a rust inhibitor to the cooling system (refer to Corrosion Inhibitors in Coolant Specifications).

4. Remove, check and recondition the injectors, if necessary, to make sure they will be ready to operate when the engine is restored to service.

5. Reinstall the injectors in the engine, time them and adjust the exhaust valve clearance.

6. Circulate the coolant through the entire system by operating the engine until normal operating temperature is reached (160-185°F or 71-85°C).

7. Stop the engine.

8. Remove the drain plug and completely drain the engine crankcase. Reinstall and tighten the drain plug. Install new lubricating oil filter elements and gaskets.

9. Fill the crankcase to the proper level with a 30-weight preservative lubricating oil MIL-L-21260, Grade 2 (P10), or equivalent.

10. Drain the engine fuel tank.

11. Refill the fuel tank with enough rust preventive fuel oil such as American Oil Diesel Run-In Fuel (LF-4089), Mobil 4Y17, or equivalent, to enable the engine to operate ten minutes.

12. Drain the fuel filter and strainer. Remove the retaining bolts, shells and elements. Discard the used elements and gaskets. Wash the shells in clean fuel oil and insert new ele- ments. Fill the cavity between the element and shell about two-thirds full of the same rust preventive compound as used in the fuel tank and reinstall the shell.

13. Operate the engine for five minutes to circulate the rust preventive throughout the engine.

PROCEDURE FOR RESTORING AN ENGINE TO SERVICE WHICH HAS BEEN IN EXTENDED STORAGE

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. DO NOT overlook the exhaust outlet.

2. Wash the exterior of the engine with fuel oil to remove the rust preventive.

3. Remove the rust preventive from the flywheel.

4. Remove the paper strips from between the pulleys and the belts.

5. Remove the drain plug and drain the preservative oil from the crank- case. Re-install the drain plug. Fill the crankcase to the proper level,

using a pressure prelubricator, with the recommended grade of lubricating oil.

6. Fill the fuel tank with the fuel specified under Diesel Fuel Oil Specifications (refer to Fuel and Oil Specifications).

7. Close all of the draincocks and fill the engine cooling system with clean, soft water and a rust inhibitor. If the engine is to be exposed to freezing temperatures, fill the cooling system with a permanent type antifreeze solution (refer to Coolant Specifications).

8. Install and connect the battery.

INTRODUCTION

The purpose of this chapter is to provide servicing information pertaining to Sundstrand's family of heavy-duty hydrostatic transmissions.

A complete review of each section for familiarization of content is suggested prior to any operations being performed.

The information is compiled to provide correct procedures for installation, startup, and system maintenance for trouble free operation of the transmissions. Any deviation of these guidelines should be investigated prior to implementation.

In working with any hydraulic equipment, cleanliness is most important. Any item related to the transmission must be clean. All tools, hose, containers, units, etc. must be protected from contaminants. This pertains whether the system is new or being serviced. Keep it clean.

HYDRAULIC CIRCUITS

The hydrostatic transmission offers in- finite control of speed and direction. The operator has complete control of the system with one lever for starting, stopping, forward motion, or reverse motion.

Control of the variable displacement, axial piston pump is the key to controlling the vehicle. Prime mover horsepower is transmitted to the pump. When the operator moves the control lever, the swashplate in the pump is tilted from neutral.

When the variable pump swashplate is tilted, a positive stroke to the pistons is created. This, in turn, at any given input speed, produces a certain flow from the pump. This flow is transferred through high pressure lines to the motor. The ratio of the volume of flow from the pump to the displacement of the motor will determine the speed of the motor output shaft. Moving the control lever to the opposite side of neutral, the flow from the pump is reversed and the motor output shaft turns in the opposite direction. Speed of the output shaft is controlled by adjusting the displacement (flow) of the transmission. Load (working pressure) is determined by the external conditions, (grade, ground conditions, etc.) and this establishes the demand on the system.

Pump and motors are contained in separate housings or may be connected by a common end cap. All valves required for a closed loop circuit are included in either the pump or motor assemblies. A reservoir, filter, cooler, and lines complete the circuit.

Fig. 1 illustrates the internal components of a typical Sundstrand heavy-duty hydrostatic transmission. Fig. 2 illustrates the general appearance of the components of a heavy-duty transmission.

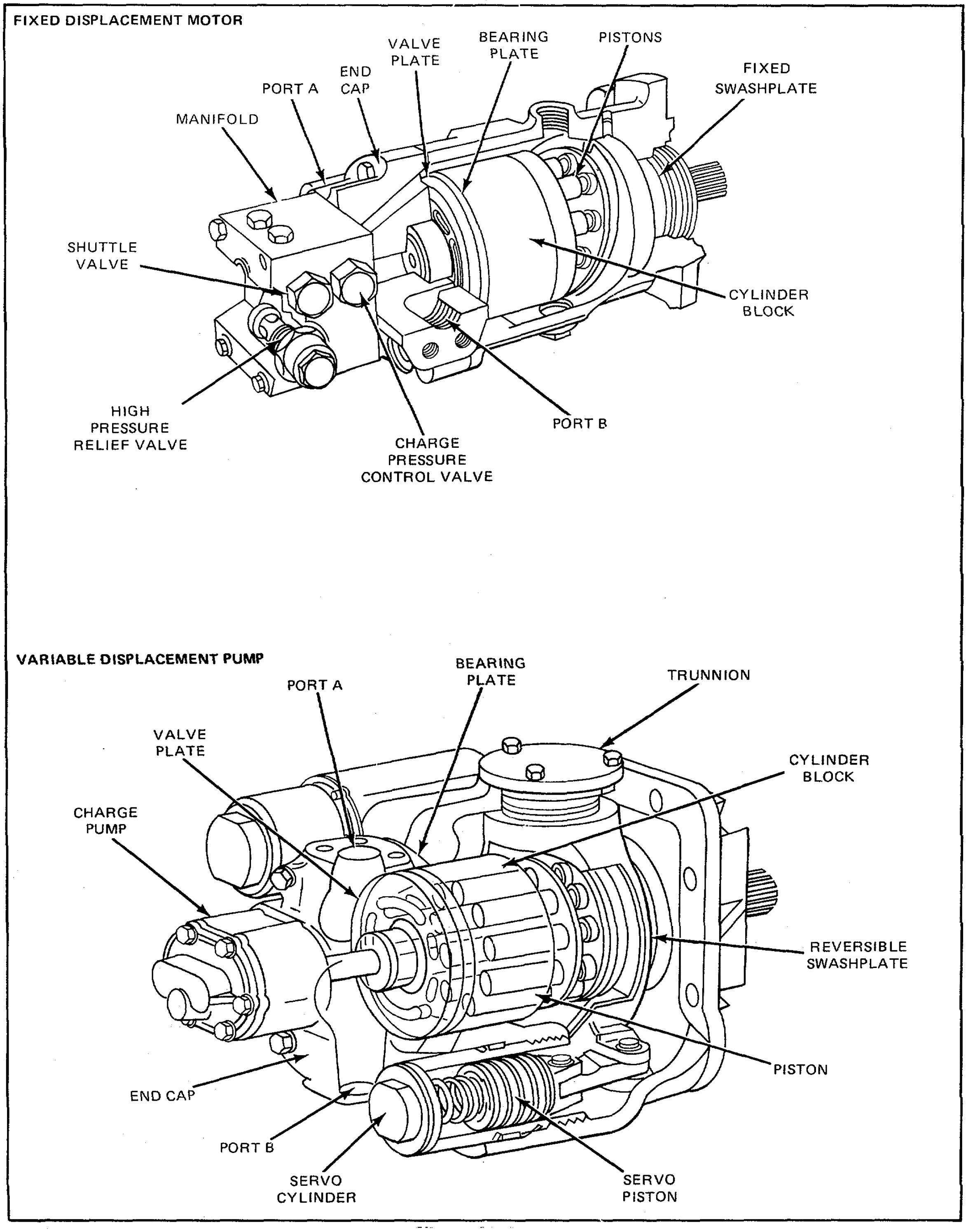

FIXED DISPLACEMENT MOTOR
VALVE PLATE
BEARING PLATE
PISTONS
END CAP
PORT A
FIXED SWASHPLATE
MANIFOLD
SHUTTLE VALVE
CYLINDER BLOCK
HIGH PRESSURE RELIEF VALVE
PORT B
CHARGE PRESSURE CONTROL VALVE
VARIABLE DISPLACEMENT PUMP
BEARING PLATE
PORT A
TRUNNION
VALVE PLATE
CYLINDER BLOCK
CHARGE PUMP
REVERSIBLE SWASHPLATE
PISTON
END CAP
PORT B
SERVO CYLINDER
SERVO PISTON

Figure 1.

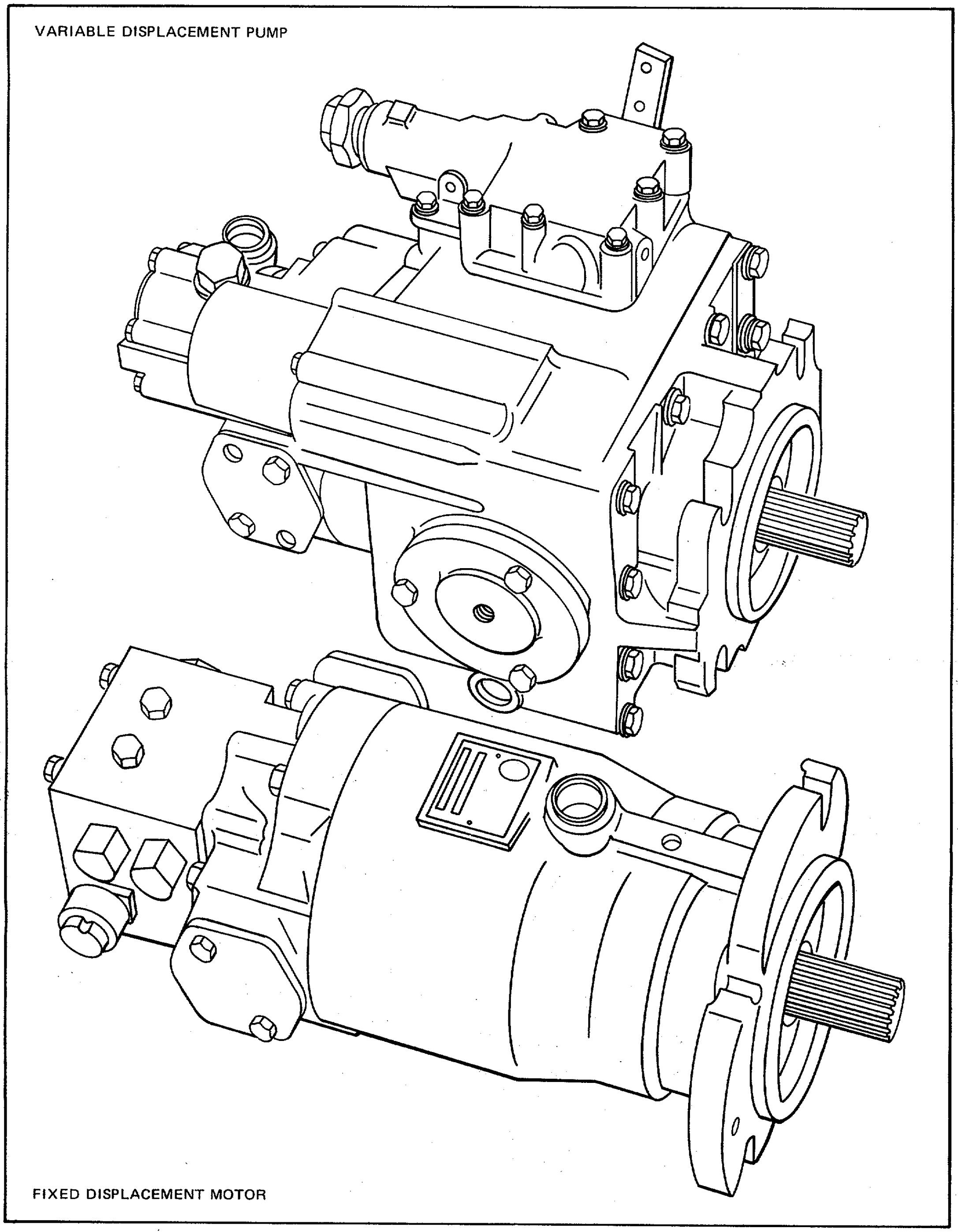


Figure 2.

CHARGE PUMP CIRCUIT

Fluid flows from the reservoir through a filter to the inlet of the charge pump mounted on the main pump which is driven at pump shaft speed. The purpose of the charge pump is to provide a flow of fluid through the transmission for cooling purposes, to supply fluid under pressure to maintain a positive pressure on the low-pressure side of the main pump/motor circuit, to provide sufficient fluid under pressure for control purposes, and for internal leakage makeup.

MAIN PUMP AND MOTOR CIRCUIT

Fluid from the charge pump is directed to the low-pressure side of the main circuit by means of one of two check valves. The second check valve is held closed by the fluid under high- pressure on the other side of the main circuit.

Fluid flows in the main circuit in a continuous closed loop. The quantity of fluid flow is determined by pump speed and displacement while direction of flow is determined by the swashplate angle from neutral.

A manifold valve assembly, connected across the main circuit, includes elements essential to provide the proper operation of the transmission. The manifold valve contains two pilot- operated, high-pressure relief valves which serve to prevent sustained abnormal pressure surges in either of the two main hydraulic lines by dumping fluid from the high-pressure line to the low-pressure line during rapid acceleration, abrupt braking and sudden application of load.

Also provided in the manifold valve as- sembly is a shuttle valve and a charge pressure relief valve. The shuttle valve functions to establish a circuit between the main line that is at low pressure, and the charge pressure-relief valve to provide a method of controlling the charge pressure level and also a means of removing the excess cooling fluid added to the circuit by the charge pump. The shuttle valve is spring centered to a closed position so that during the transition of the reversing of pressures in the main lines, none of the high-pressure fluid is lost from the circuit.

COOLING CIRCUIT

Excess cooling fluid from the manifold charge pressure-relief valve enters the motor case, then flows through case drain lines to the pump case, through the pump case and heat exchanger to the reservoir. The heat exchanger bypass valve is used to prevent high-back pressure at the heat exchanger due to cold fluid or a restricted heat exchanger.

During periods of operation when the main pump is in neutral, the shuttle valve will be centered and the excess flow from the charge pump is directed to the cooling circuit by the neutral charge relief valve in the charge pump. When operating at this condition, cooling flow is not admitted to the motor case, but through the pump case and heat exchanger to the reservoir.

TYPICAL HEAVY DUTY VARIABLE PUMP-FIXED MOTOR TRANSMISSION SCHEMATIC

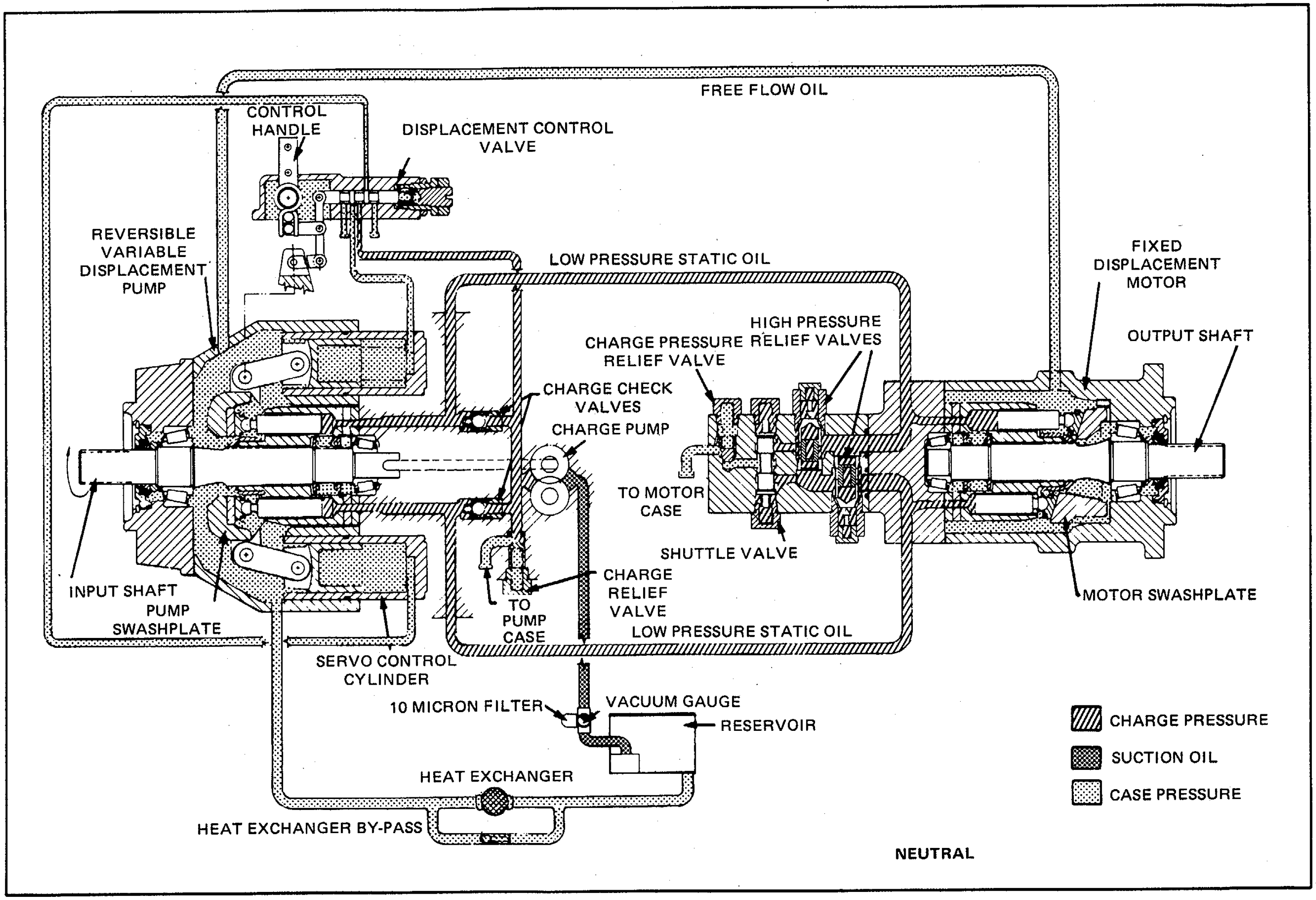


Figure 3.

TYPICAL HEAVY DUTY VARIABLE PUMP-FIXED MOTOR TRANSMISSION SCHEMATIC

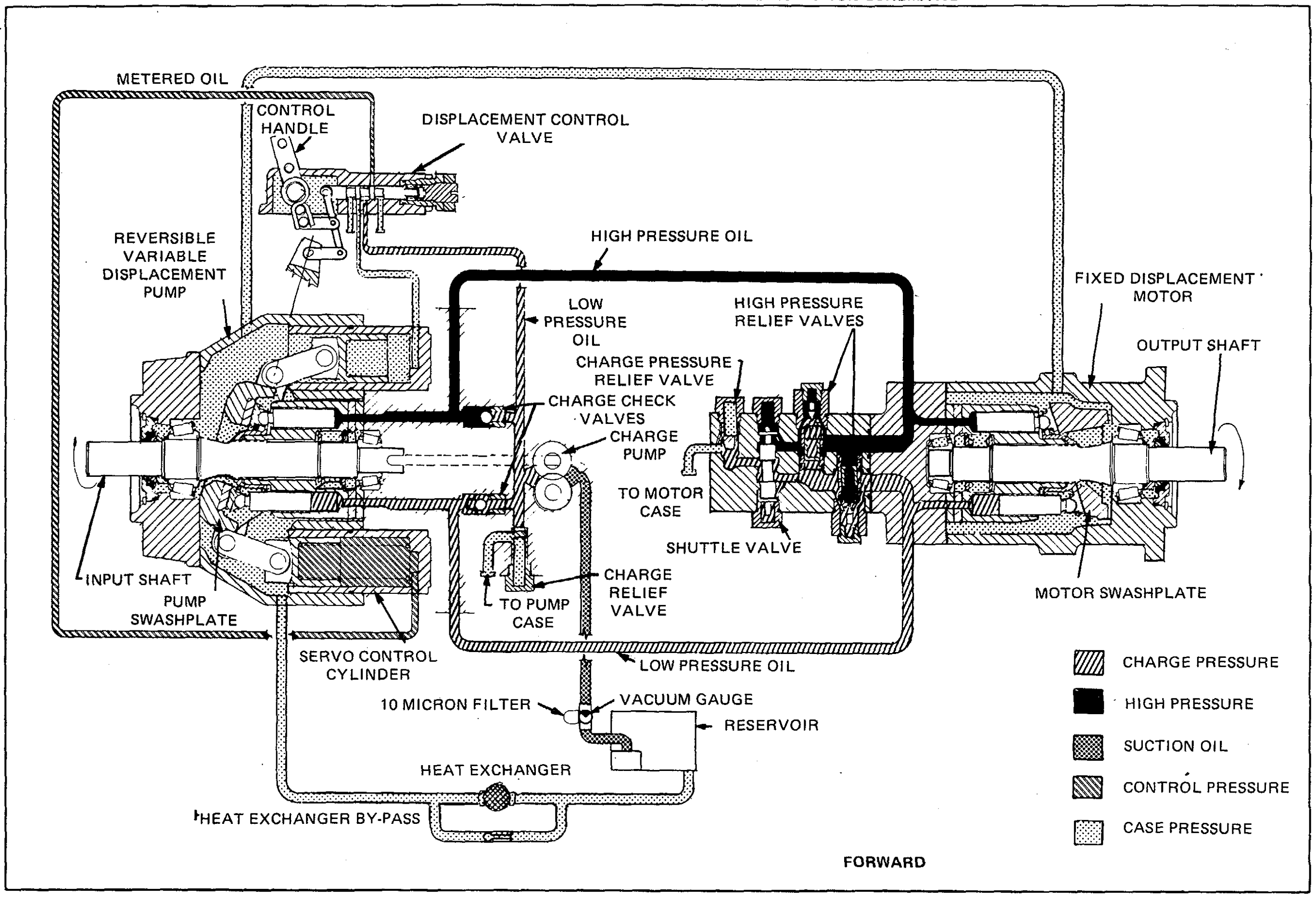


Figure 4.

TYPICAL HEAVY DUTY VARIABLE PUMP-FIXED MOTOR TRANSMISSION SCHEMATIC

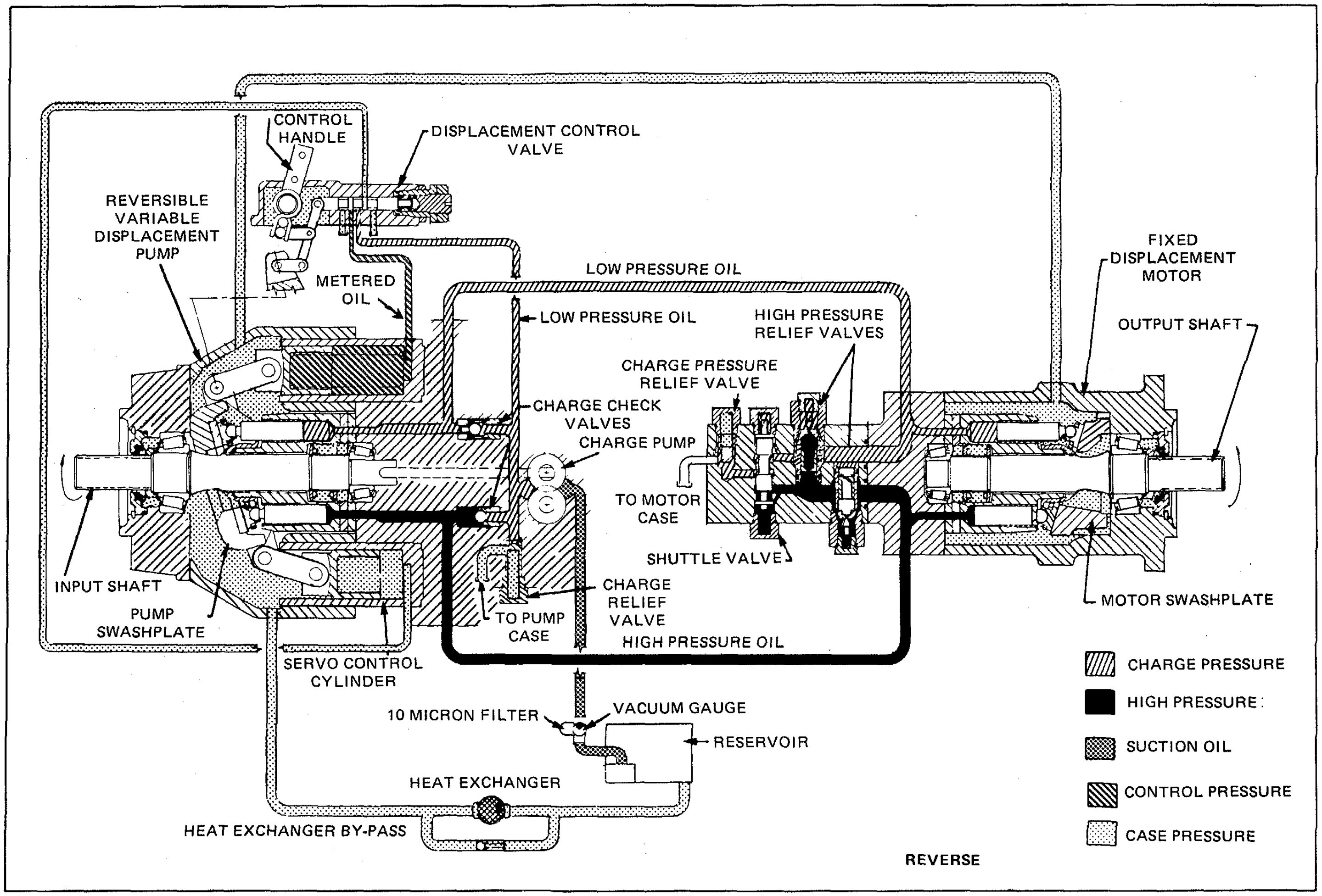


Figure 5.

TYPICAL HEAVE DUTY VARIABLE PUMP VARIABLE MOTOR TRANSMISSION SCHEMATIC

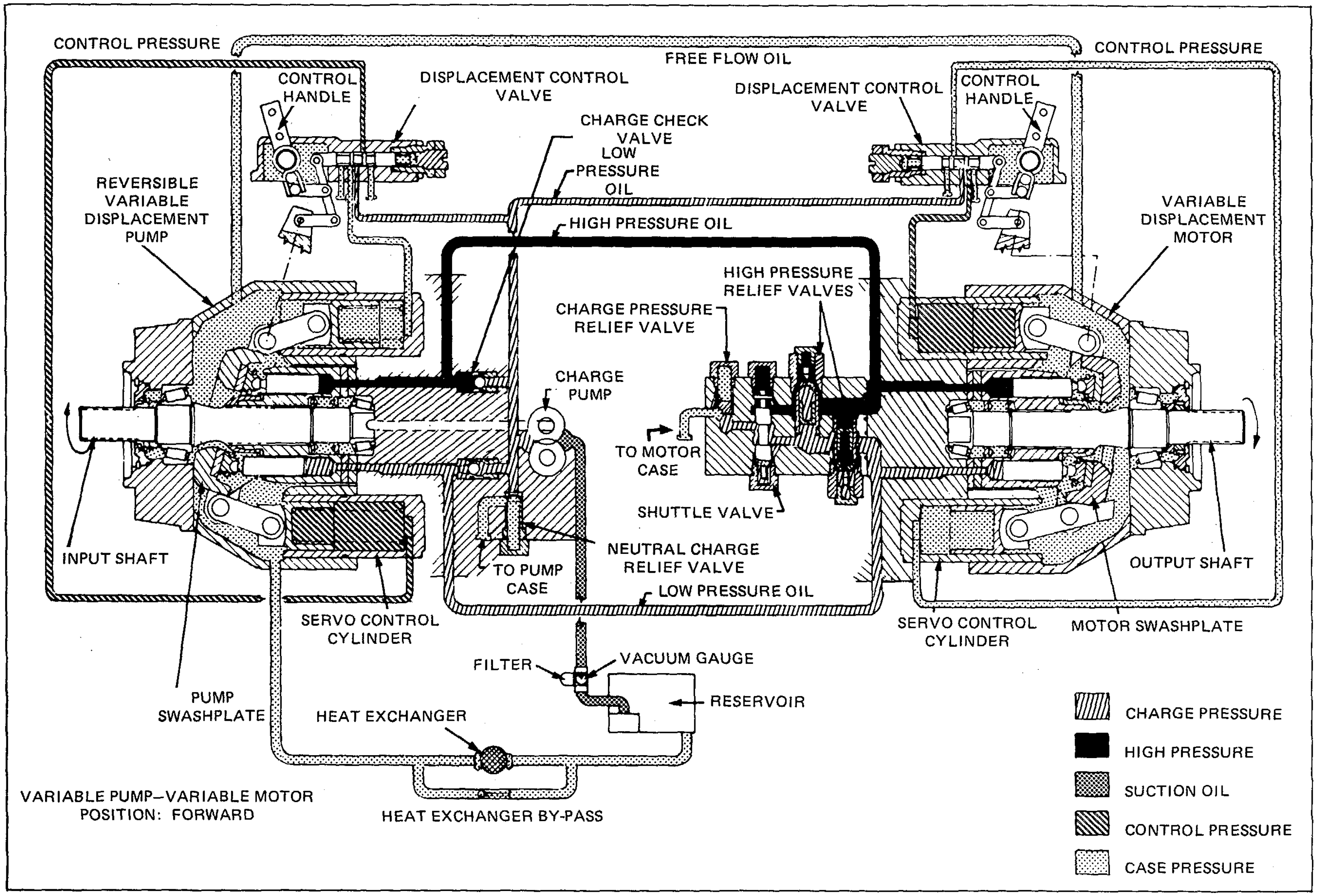


Figure 6.

TYPICAL HEAVE DUTY VARIABLE PUMP - FIXED MOTOR TRANSMISSION SCHEMATIC WITH PRESSURE OVERRIDE VALVE

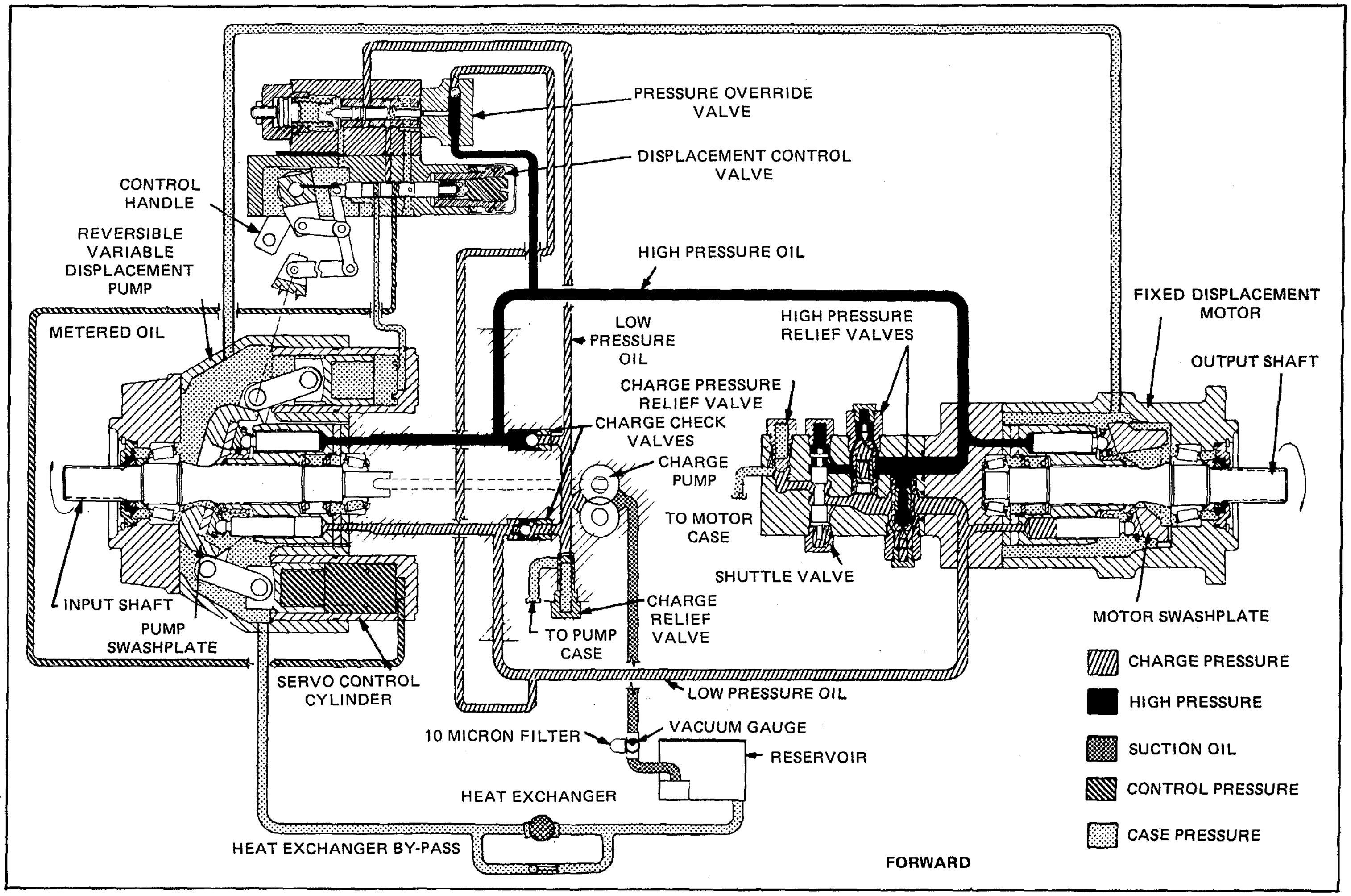


Figure 7.

CONTROLS

Various types of controls are available: i.e., displacement, pressure override and rotary by-pass.

DISPLACEMENT CONTROL OPERATION

The Sundstrand heavy-duty variable pumps incorporate a powered servo system to control the swashplate position with a correspondingly low operator effort.

The valve assembly is a closed center four-way valve with the servo pressure ports exhausted at the center position. The valve is operated through internal linkage connections with both the swashplate and the external control handle. (Refer to Fig. 1.)

To put the pump in stroke, the control handle (A) moves the displacement control spool (B) through a spring (C). The spool ports oil under charge pressure (D) to a servo cylinder (E). The piston moves the swashplate (F) against the opposite servo spring (G). Both servo springs are constrained so that they can only force the swashplate toward neutral. When the swashplate has moved to the angle set by the control handle, the feed-back link (H) returns the displacement control spool almost to neutral where it ports just enough oil to the servo cylinder to keep the swashplate at the proper angle.

The orifice (K) restricts the incoming charge supply to limit the maximum servo response rate. Spring (C) allows the operator to rapidly pre-select the desired speed setting without waiting for the swashplate to follow-up.

When the control handle is released, the displacement control spool is returned to neutral by a spring (J). This allows oil from both servo cylinders to flow into the pump case through the small underlaps (I). (Refer to Fig. 2.) Both servo cylinders are thus exhausted and one of the servo springs mechanically forces the swashplate to neutral.

PRESSURE OVERRIDE CONTROL OPERATION

The pressure override control is used in conjunction with Sundstrand heavy-duty variable pumps equipped with a displacement control valve. The pressure override control will override the displacement control at a predetermined system pressure, known as override pressure.

The pressure override control valve assembly is a three-way valve with charge pressure (supply pressure) ported to the displacement control in the normally open position. In the closed position, the supply pressure is cut off to the displacement control and the control is allowed to drain to tank.

During normal operation, the transmission system pressure is below the override pressure, and the pressure override valve is in the open position and therefore, does not affect the displacement of the variable pump. Thus, the displacement of the variable pump is controlled by the displacement control during normal operation.

The pressure override control valve will override the displacement control and will control the displacement of the variable pump when the load re- quires a system pressure above the override pressure. During this mode of operation, a ball check senses the pressure from both sides of the loop and ports the higher pressure into cavity (A) (refer to Fig. 3) and against signal piston (B). The signal piston (B) forces the controlling spool against a spring (D). As system pressure increases, the spool (C) moves toward the spring (increased force on

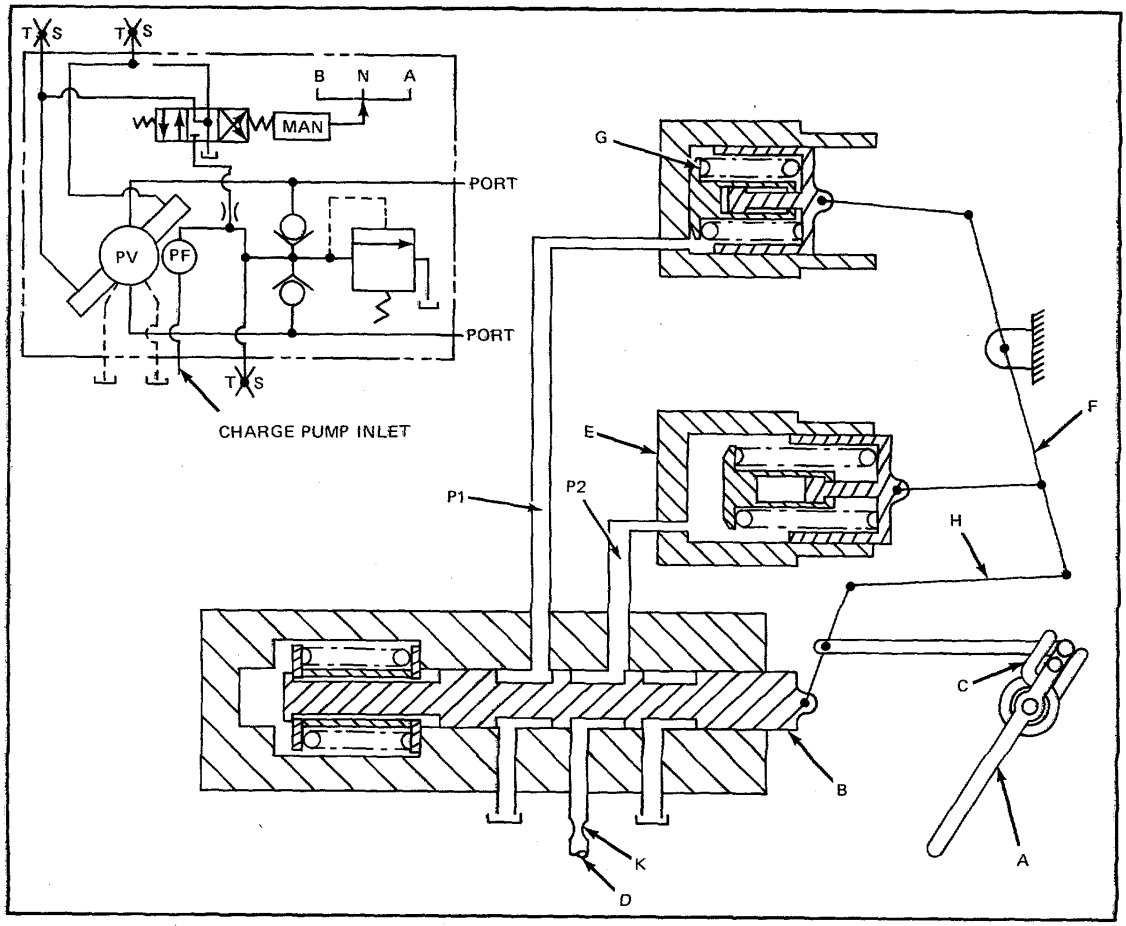


Figure 1. Displacement Control Valve Out of Neutral and Swashplate Moving Into Stroke

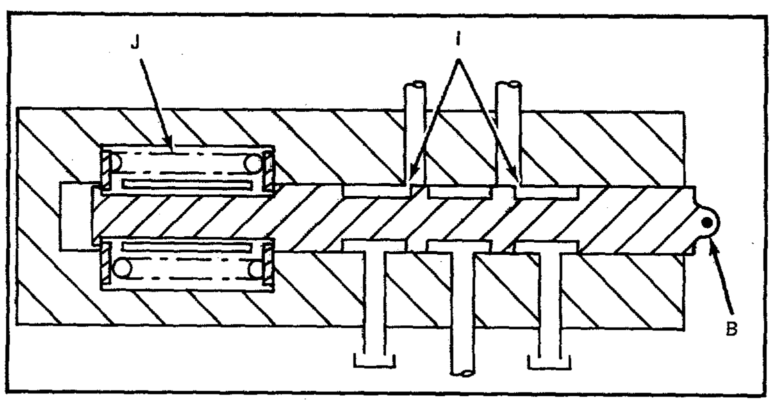


Figure 2. Displacement Control Valve in Neutral

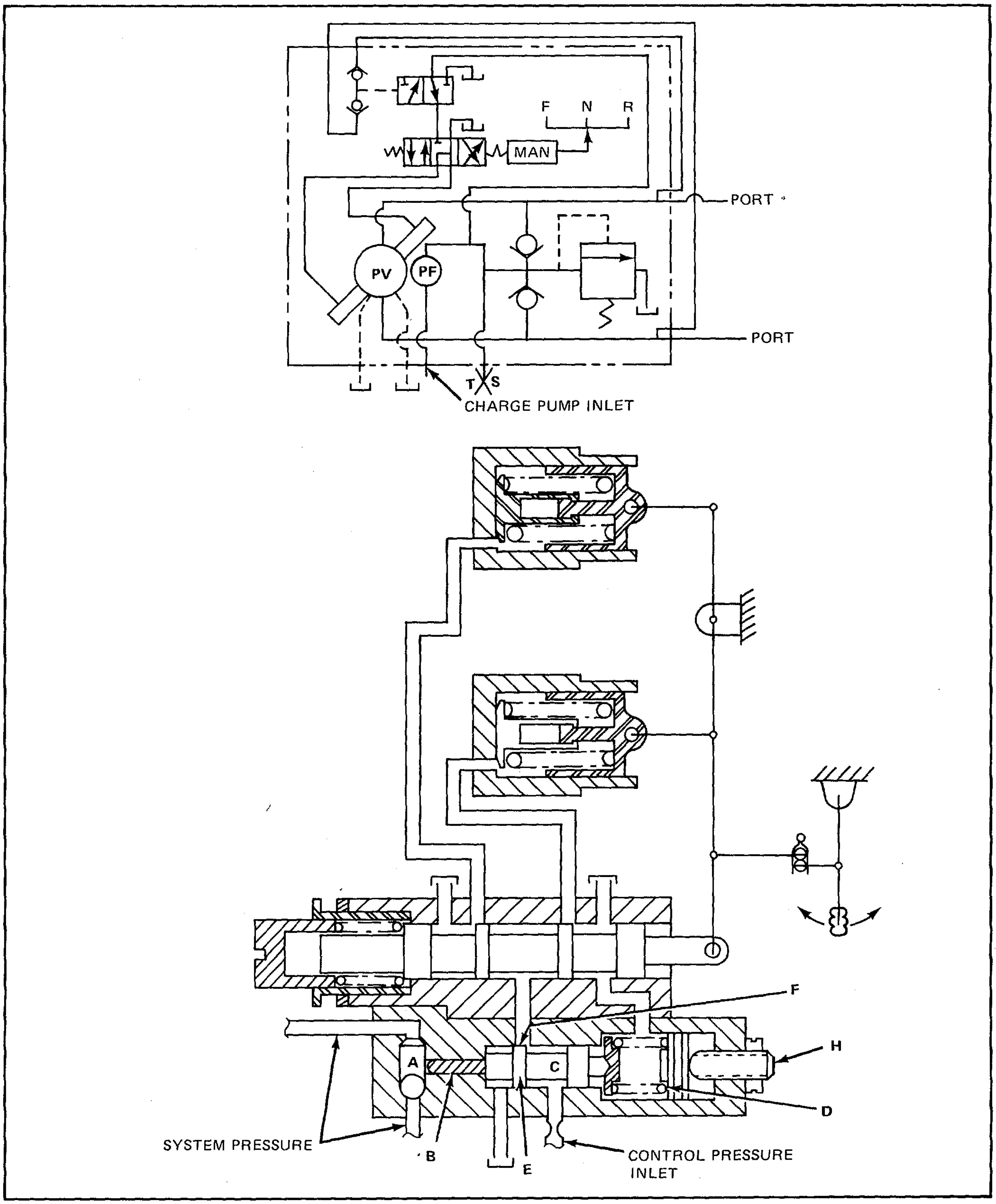


Figure 3. Pressure Override Control

spring also increases spring deflection) until controlling land (E) on the spool covers the controlling port (F). The override pressure is defined as the system pressure when land (E) covers port (F).

As the system pressure increases above the override pressure, the spool and land (E) shift further toward the spring and the port (F) is opened to the tank, thus draining the pressurized servo cylinder and allowing displacement of the variable pump to decrease.

The pressure override will modulate so that a servo pressure is maintained, to maintain a displacement which will yield a system pressure equal to the override pressure.

The override pressure is adjustable by turning the screw (H) and varying the preload on the spring. The override pressure will vary approximately 1000 psi per full turn of the screw (H).

ROTARY BYPASS OPERATION

The rotary bypass valve is used in conjunction with a Sundstrand manifold valve assembly which is normally associated with a Sundstrand Variable or Fixed Motor. The rotary bypass valve cross ports flow across the motor (load).

The rotary bypass valve assembly is a two-way valve (refer to Fig. 4). In the closed position, the valve is blocked and has no function to the system. In the open position, the valve ports fluid from side (A) of the closed loop to side (B) or vice versa.

The rotary bypass valve is to be used only in the full-open or full-closed position. The valve should not be used to control the speed of the motor as undesirable heat will be generated.

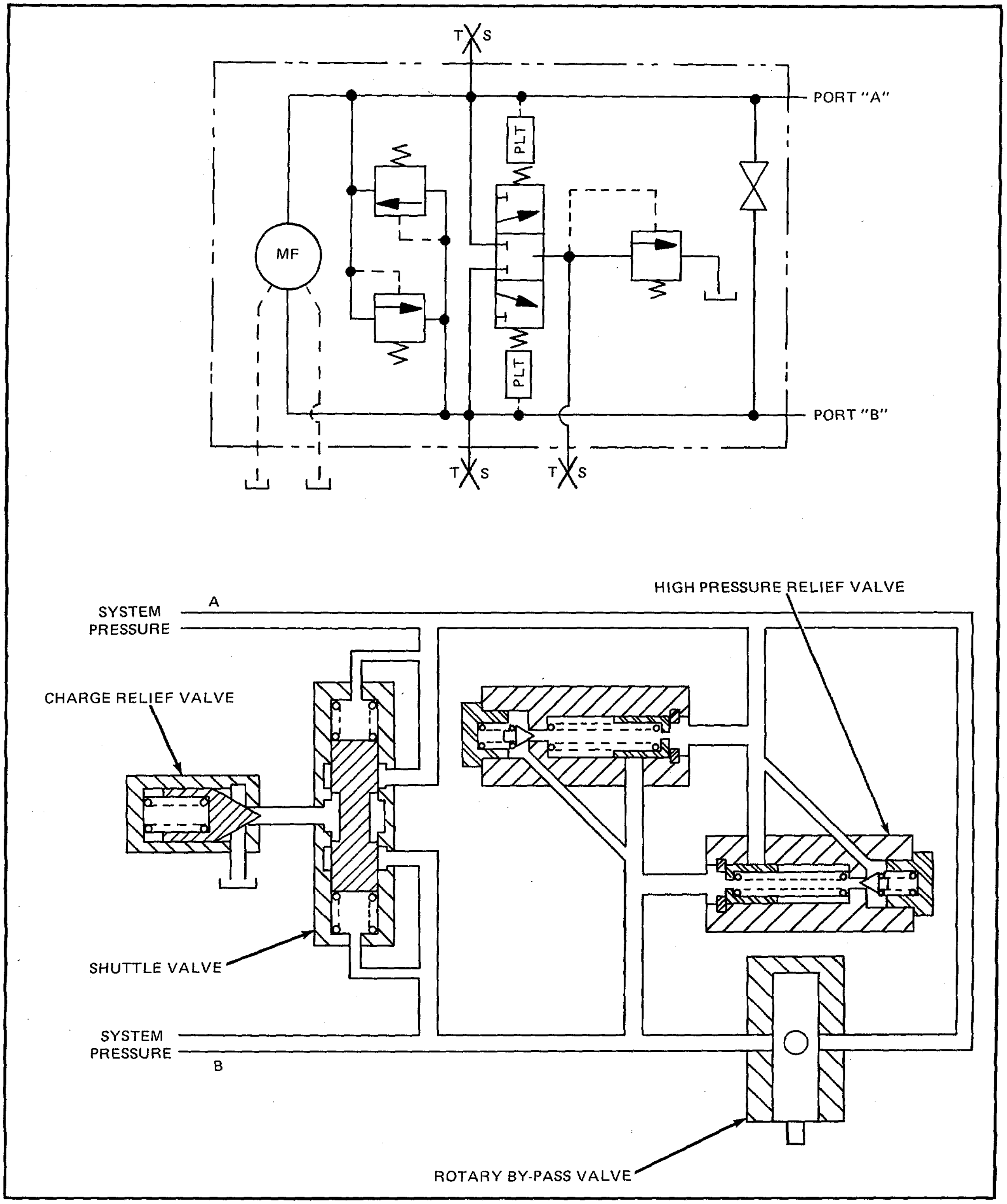


Figure 4. Rotary Bypass Valve

INSTALLATION AND PLUMBING

The system in which the hydrostatic pump and motor is operated should provide an environment compatible with the requirements of the transmission.

The requirements of the complementary components necessary to complete the hydraulic circuitry are described below.

The arrangement of the components and their respective sizes are shown on Fig. 1, and *Plumbing Reference Chart.*

COMPLEMENTARY COMPONENTS

RESERVOIR (FIG. 1, ITEM 1)

A suggested minimum reservoir volume (in gallons) is five-eighths of the total charge pump flow per minute (in gpm) with a minimum fluid volume equal to one-half charge pump flow. This minimum reservoir volume will provide for a minimum of 30 seconds fluid dwell at the maximum reservoir return flow in the system.

The outlet port to the charge pump inlet must be positioned above the bottom to take advantage of gravity separation and prevent any large foreign particles from entering the suction line. A 100 mesh screen is recommended over the outlet port to further assist large particle separation. The fluid level in the reservoir must always be above the outlet port.

The reservoir inlet (fluid return) should be positioned in such a way that return flow is directed into the interior of the reservoir to provide for maximum dwell and most efficient deaeration of the fluid.

A drain in the reservoir is recommended which would permit a complete fluid change without disconnecting other normal hydraulic connections. This would also provide a water drain and permit flushing in the event of excess system or component contamination.

A filler port (FIG. 1, ITEM 12) should be provided that minimizes the potential for contamination entering the system during servicing or during operation. A closed reservoir is recommended to reduce introduction of contamination and be designed so that the recommended charge pump inlet pressure and case drain pressures are not exceeded. (Refer to *Troubleshooting for Pressure Limits*.)

RESERVOIR SHUTOFF VALVE (FIG. 1,
ITEM 2)

It is recommended that a shutoff valve be installed between the reservoir outlet and filter inlet, on those systems incorporating a filter installed outside the reservoir to facilitate a filter change without a large loss of fluid and to minimize system contamination.

The minimum inside diameter of the valve should be equal to or greater than the inside diameter of the charge pump inlet line so that the recommended charge pump inlet pressures are not exceeded. (Refer to *Troubleshooting for Charge Pump Inlet Pressure*.)

FILTER (FIG. 1, ITEM 3)

The fluid supplied to the charge pump system must be filtered by a good quality 10 micron nominal rated suction filter and shall not incorporate a bypass valve. This type of filtration system will give the greatest degree of reliability in keeping the system free of contamination. Filter clogging causing reduced inlet pressure to the pump beyond limits specified will eventually result in reduced transmission control response. The transmission

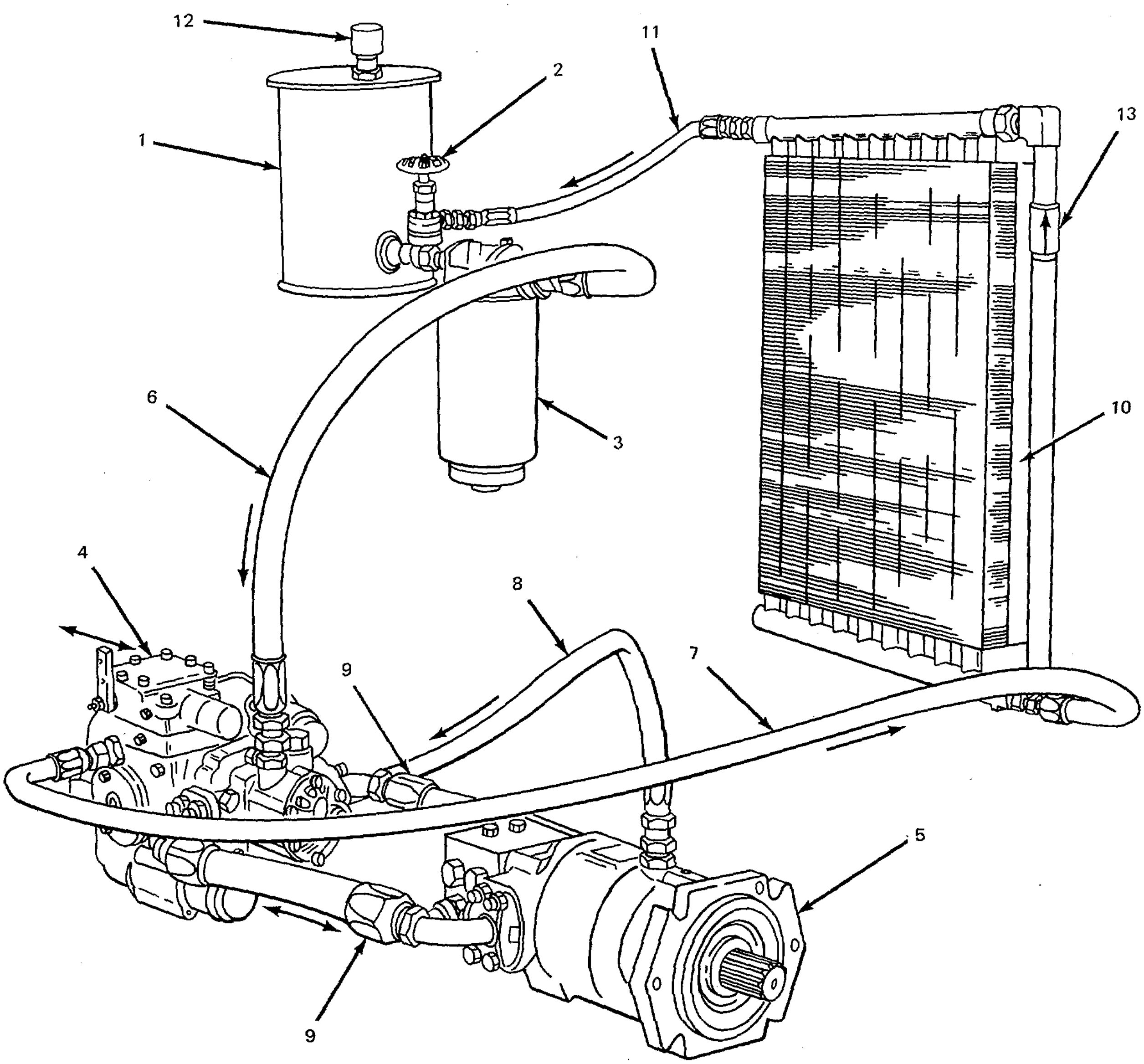


Figure 1. Plumbing Installation Variable Pump-Fixed Motor

will become slow and sluggish. This will occur before any damage to the transmission results and provide ample indication that a filter element change is required.

All filter cartridges should be sufficiently strong to prevent collapse or rupture under the most adverse operating conditions.

HEAT EXCHANGER (FIG. 1, ITEM 10)

Provisions should be made in the system to ensure that the maximum continuous operation temperature shall not exceed 180°F at the motor case drain. This may require the use of a heat exchanger in the reservoir return circuit, dependent upon the specific duty cycle and design of the machine. Generally, the optimum heat exchanger size should be capable- of dissipating 20-25% of the maximum transmission input horsepower.

The fluid restriction resulting from the case drain lines and heat exchanger should not exceed 40 psi case pressure at normal system temperature. This may require the use of a pressure bypass around the heat exchanger (Fig. 1, Item 3).

HYDRAULIC FLUID

The hydraulic fluid used in the system should be selected using the guidelines given in the fluid recommendations in *Transmission Startup*.

HYDRAULIC LINES (FIG. 1, ITEMS 6, 7, 8, 9 AND 11)

The hydraulic lines selected should be compatible with good hydraulic practices regarding length, diameter, pressure capabilities, bend radii, fluid compatibility, and transmission operating limits.

ITEM NO.	SERIES SIZE	INLET PORT CONNECTION	CASE PORT CONNECTION	HIGH PRES. PORT CONNECTION	MINIMUM HOSE ID	MINIMUM TUBING OD	REMARKS
1. Reservoir	All Series	-	-	-	-	-	Refer to Page 480, Installation and Plumbing.
2. Shutoff Valve	All Series	-	-	-	-	-	Minimum Inside Diameter should equal minimum diameter of Ref. No. 6
3. Filter	All Series	-	-	-	-	-	Refer to Page 480, Installation and Plumbing.
4.	TYPICAL VARIABLE PUMP						
5.	TYPICAL FIXED MOTOR						
6. Inlet Line	20, 21, 22, 23	7/8-14 SAE strght thrd. O-ring boss	-	-	3/4 inch	3/4 inch	1 inch minimum diameter with 1.6 cubic inches charge pump
	24, 25, 26, 27	1 5/16-12 SAE strght thrd. O-ring boss	-	-	1 inch	1 inch	1 1/4 inches diameter with 4 cubic inches charge pump; Connections is 1 1/4 inches SAE split flange boss
	28	1 1/4 inches SAE split	-	-	1 1/4 inches	1 1/4 inches	All hose sizes-SAE 100R4 or equivalent construction

ITEM NO.	SERIES SIZE	INLET PORT CONNECTION	CASE PORT CONNECTION	HIGH PRES. PORT CONNECTION	MINIMUM HOSE ID	MINIMUM TUBING OD	REMARKS
7-8. Pump and Motor Case Drain Lines	20, 21, 22, 23 24	-	7/8-14 SAE strght thrd O-ring boss	-	5/8 INCH	5/8 INCH	All Hose sizes-SAE 100R3 or equivalent
	24, 27	-	1 5/16-12 SAE O-ring boss	-	1 inch	1 inch	
	26, 28	-	1 7/8-12 SAE O-ring boss	-	1 1/2 inches	1 1/2 inches	
9. High-Pressure	20, 21 22, 23 24	-	-	1 inch SAE split flange 3000 psi	1 inch 1 ½ inches	1 inch 1 ½ inches	Optional: 1-6000 SAE split flange and 1 5/16-12 strght thread SAE O-ring boss. All sizes four wire spiral minimum construction hose
	25, 26 27	-	-	1 ½ inches SAE split flange 6000 psi	1 ½ inches	1 ½ inches	
10. Heat Exchanger	All Series	-	-	-	-	-	The Optimum heat exchanger size selected should be able to dissipate 20-25% of the transmission input horsepower
11. Reservoir Return Line	All Series	-	-	-	Same size as Ref No. 7 and 8		-

ITEM NO.	SERIES SIZE	INLET PORT CONNECTION	CASE PORT CONNECTION	HIGH PRES. PORT CONNECTION	MINIMUM HOSE ID	MINIMUM TUBING OD	REMARKS
12. Fillcap or Breather	-	-	-	-	-	-	See page 1 Installation and plumbing (Reservoir)
13. Heat Exchanger Bypass Valve	All	-	-	-	-	-	Valve should open at approximately 15 psi

TRANSMISSION STARTUP

PROCEDURE

1. After the transmission has been installed, remove the threaded plug from the side of the main pump housing (refer to Fig. 9, Item A).

For reading charge pressure at this port, install a 600 psi gage, with a short section of hose. The threaded port is 7/16 x 20 straight thread O-ring. Also install at the charge pump inlet a vacuum gage for reading inlet vacuum (refer to Fig. 9).

2. Check all fittings to be sure they are tight.

3. When filling any area of the transmission, it is recommended that all fluid be passed through a ten-micron filter (refer to *Fluid Recommendations*).

Fill the pump and motor cases through the upper case drain opening with a recommended fluid. Reinstall and tighten case drain lines.

4. Loosen the charge pump line, coming from the filter/reservoir, at the inlet to the charge pump.

5. Fill the reservoir with fluid. When fluid appears at the loosened hose at the charge pump inlet, install and tighten the hose and continue filling the reservoir. Leave reservoir cap loose so air will escape.

If gravity feed does not fill the inlet line to the charge pump, it must be filled by hand.

6. It is recommended that the control linkage to the pump control valve be left disconnected until after the initial startup. This will allow the pump to remain in positive neutral.

7. If the prime mover is:

Engine: (Diesel)

Close the injector rack, turn the engine over until the charge pressure reaches 30 psi or more.

8. Start the prime mover and if possible, maintain a 750 rpm pump shaft speed for 5 minutes. This will allow the system to fill properly. During this phase, pressure surges may be seen on 600 psi gage. THIS IS NORMAL.

While running at 750 rpm idle, the pump charge pressure must be at least 100 psi above case pressure. If it is not, shut down and troubleshoot. (Refer to *Troubleshooting*.)

9. Increase pump speed to approximately 100 rpm; charge pressure on the 600 psi gage should be 190-210 psi above pump case pressure. (See Note.)

10. Shut down prime mover and connect linkage to the displacement control valve handle.

CAUTION

If the motor shaft is connected to the drive mechanism, the necessary safety precautions must be considered.

11. Check fluid level in reservoir and add if necessary.

12. Start prime mover and run the pump at 1500 to 1800 rpm; charge pressure should be 190-210 psi above pump case pressure.

13. Move the pump control handle slowly to the forward and then the reverse position. Charge pressure will drop to 160-180 psi above motor case pressure.

Repeat or continue to cycle for approximately 5 minutes.

14. Should the charge pressure fall below 100 psi above motor case pressure, discontinue startup until trouble has been found. (Refer to *Troubleshooting*.)

15. Run the prime mover at maximum RPM with the pump in neutral. Observe the reading at the vacuum gage connected to the charge pump inlet. This reading should not exceed 10-inches of mercury at normal operating conditions.

16. Shut down prime mover, remove all gages and replace all plugs or lines. Check reservoir fluid level and tighten oil fill cap. The machine is now ready for operation.

NOTE

On those pumps equipped with a 4-cubic-inches/rev. charge pump, the charge pressure should be:

A. 210-240 psi above pump case pressure - pump in neutral at 1000 rpm

B. 300-385 psi above pump case pressure - pump in neutral at 1500-1800 rpm

C. 230-250 psi above motor case pressure - pump in stroke at 1500-1800 rpm

FLUID RECOMMENDATIONS

HYDROSTATIC TRANSMISSIONS

Hydraulic fluids selected for use with the Sundstrand hydrostatic transmission should be a quality product carefully selected with assistance from a creditable supplier.

Characteristics of the fluid selected should include:

Viscosity
Oxidation
Thermal Stability
Shear Stability
Low Temperature Fluidity
Antiwear
Anticorrosion
Antifoam
Seal Conditioning for Buna-N and Viton Elastomers

The following types of fluids have been used successfully in the hydro- static transmission: (1) antiwear hydraulic oil, (2) automatic trans- mission fluid - Type-F, and (3) hydraulic transmission fluid (type used by the Agricultural industry for combined transmission, hydraulic and wet brake systems). If a fire resistant fluid is required, Pydraul 312 has been satisfactory.

Most of the above fluid types have acceptable viscosity characteristics in the operating range of 0°F to 200°F. The fluids selected should provide a minimum viscosity of 47 SUS at 210°F and a maximum measured viscosity of 6000 SUS at the lowest expected startup temperature. Typical fluid properties are listed on the attached table.

Fluid Type	Typical 0°F	Viscosity 100°F	SUS 210°F	Viscosity Index	Pour Point °F	Operating Range (Typical °F)
Antiwear Hydraulic Oil	7000	200	50	130	-30	0-200°F
Type-F	3200	212	57.2	208	-40	-15-200°F
Hydraulic Transmission Oil	12,000	233	49	100 Min.	-35	0-200°F
*Pydraul 312	100,000	312	51	77	-10	50-200°F

*Fire Resistant Fluid

TROUBLESHOOTING PROCEDURE

HYDROSTATIC SYSTEM

NOTE

Before proceeding with troubleshooting, read the following information.

Sundstrand heavy-duty transmissions must maintain various pressures to function properly. Any disturbance of the proper pressure levels will lead to an inoperable transmission.

Four pressures normally must be monitored to accurately diagnose a malfunction in the transmission:

1. CHARGE PUMP INLET SUCTION: The maximum vacuum at the charge pump inlet should not exceed 10-inches of mercury at normal operating conditions. It is acceptable for the inlet vacuum to exceed 10-inches of mercury during cold startup.

2. CHARGE PRESSURE: The minimum allowable charge pressure is 130 psi above case pressure. Normal charge pressure is 160 psi above motor case pressure when the motor shaft is turning and 190 psi above pump case pressure when the pump is in neutral.

3. SYSTEM OR HIGH PRESSURE: The maximum system pressure obtainable is controlled by the high-pressure relief valves located in the motor manifold. The relief valves have a two-digit number stamped on the exposed end stating valve setting (i.e. "50" = 5000 psi).

4. CASE PRESSURE: The transmission case pressures should not exceed 40 psi gage under normal operating conditions.

Proper troubleshooting procedures dictate that the pressure levels developed in the circuit must be known by the installation and interpretation of the pressure gages.

The necessary gages and complimentary equipment required are depicted in Fig. 1. Their proper installation in the circuit is depicted in Fig. 2.

NOTE

For accurate gage interpretation, it is recommended that the pump drive shaft be turning at or near maximum rpm.

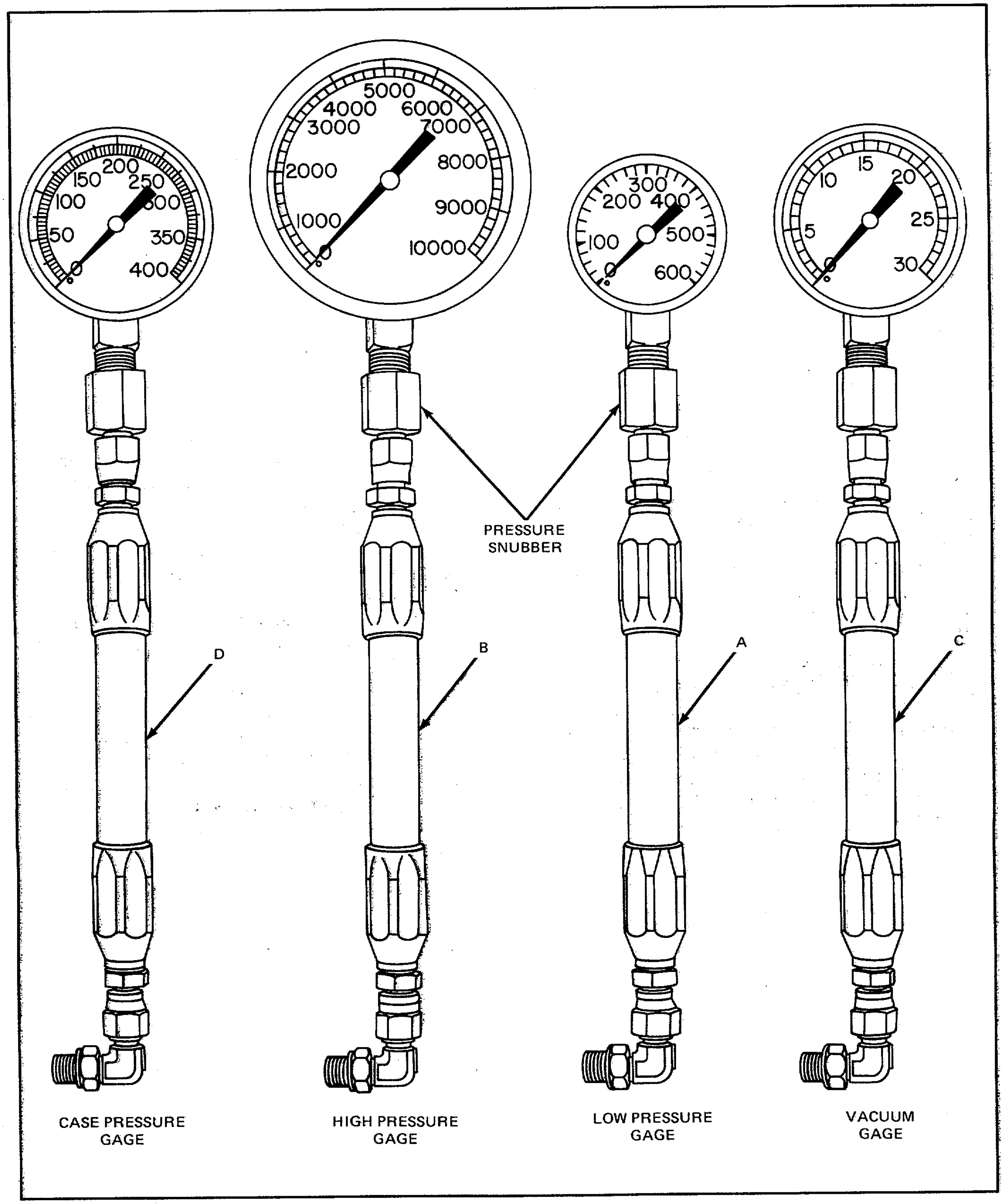


Figure 1. Troubleshooting Gages

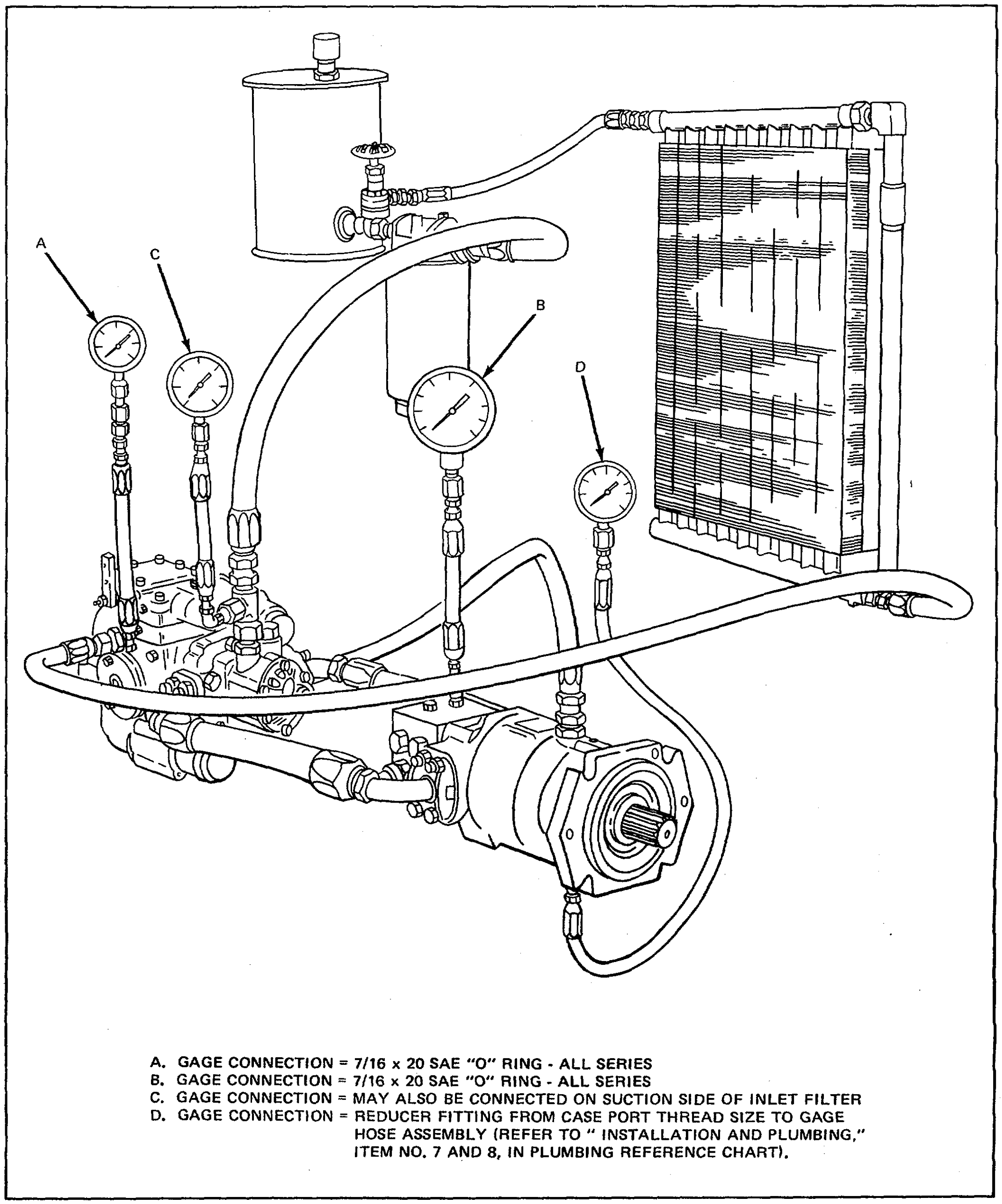


Figure 2. Typical Gage Installation (PV-MF)

TROUBLESHOOTING PROCEDURE

I. SYSTEM WILL NOT OPERATE IN EITHER DIRECTION

	CAUSE	INDICATED BY	REMEDY
A.	System low on fluid	Low or zero charge pressure	1. Locate and fix leaks causing the loss of fluid. 2. Replenish fluid in reservoir to proper level.
B.	Faulty control linkage		1. Check the entire linkage, from control lever to pump arm, to make sure it is connected and free to operate as it should. Adjust linkage to pump arm. DO NOT move pump arm to meet linkage.
C.	Disconnected coupling		1. Check to see that the coupling from the engine to the pump shaft or the coupling from the motor shaft to the driven mechanism is not slipping or broken.
D.	Filter or suction line from reservoir to charge pump plugged or collapsed	High vacuum and low charge pressure	1. Replace or clean filter and/or suction line.
E.	Charge pressure relief valve in charge pump or motor manifold damaged or stuck open,	Low or zero charge pressure **NOTE** If problem is in charge pump, pressure will be low or zero when pump is in neutral. If in manifold, pressure will be low when in stroke.	1. Replace faulty assembly. (Refer to *Repair Procedure*.)
F.	Charge pump drive key or shaft broken	Zero charge pressure when pump is in neutral or when trying to go into stroke	1. Replace charge pump assembly. (Refer to *Repair Procedure*.)

CAUSE		INDICATED BY	REMEDY
G.	Internal damage to pump or motor or both	Low or zero charge pressure. Charge pressure may also fluctuate rapidly or fall to or near zero when maximum system pressure is reached	1. A check of the individual unit leakage is necessary to determine whether the damage is in the pump(s) or motor(s). Before proceeding to replace either unit, use the following procedure:
		Maximum system pressure capability in both forward and reverse is less than normal high-pressure relief valve setting	
		Pieces or flakes of brass in reservoir or filter	A. To check fixed displacement motors:
		Noisy unit (pump or motor)	(1) Remove the charge pressure relief valve cap in the motor manifold, remove the charge relief spring, insert a solid shim of sufficient length in place of the spring and reinstall cap. This will block the relief valve in a fully closed position. (2) Remove the motor case drain line where it connects to the pump case port and seal pump case with the proper size threaded plug. (3) Insert a suitable flow measuring device capable of measuring at least 100% charge pump flow in the motor case drain line (See Note.) Complete the circuit by discharging the line to the reservoir. (4) Start the prime mover and run the pump in neutral at maximum speed. (5) Engage the pump control slowly and maintain the highest possible system pressure.

	CAUSE	INDICATED BY	REMEDY
			(6) Record the amount of flow in gallons per minute out the motor case drain line. If the amount of flow is more than 50% of the charge pump flow, the motor is damaged and must be replaced. It is recommended if the motor is damaged that the pump also be replaced. **NOTE** The amount of charge pump flow may be determined by the following formula:

$$\underset{\text{(GPM)}}{\text{Charge Pump Flow}} = \frac{\text{Charge Pump Displ. x Pump Speed x 0.92}}{231}$$

	CAUSE	INDICATED BY	REMEDY
			If the motor is not damaged, the pump is faulty and must be replaced. 2. Replace pump or motor or both. (Refer to Repair Procedure.)
H.	Disconnected control valve internal linkage	Neutral charge pressure will be maintained, but pump will not go into stroke. Handle moves freely	1. Disconnect control linkage at directional control arm. Move control arm back and forth by hand. If it moves freely with no resistance, the control valve should be removed and checked for broken or missing parts. (Refer to Repair Procedure.)
J.	Plugged control orifice	Neutral charge pressure will be normal but pump will not go into stroke	1. Remove the bolts that hold the control housing to pump and check the orifice.

	CAUSE	INDICATED BY	REMEDY
			CAUTION Do not allow the orifice or O-rings to fall into the pump case. (Refer to *Repair Procedure*.)
K.	Rotary bypass valve, if used, open (located on motor manifold assembly)	Loss of system pressure in both directions Charge pressure will be normal; system temperature will be higher than normal	1. Close rotary valve.
L.	If pressure override valve is used, adjusted too low, check ball missing, or broken parts	Charge pressure will be normal If adjusted too low, system pressure will be lower than normal If check ball is missing, system will not develop pressure If broken parts, system pressure would be low or erratic	1. Readjust valve to proper setting. 2. Remove valve and repair or replace. (Refer to *Repair Procedure*.)

II. SYSTEM OPERATES IN ONE DIRECTION ONLY

	CAUSE	INDICATED BY	REMEDY
A.	Faulty control linkage		1. Check the entire linkage to make sure it is connected and free to operate as it should. Adjust linkage to the pump arm. DO NOT move pump arm to linkage. 2. Make sure the control-stop, if used, is not out of adjustment.

	CAUSE	INDICATED BY	REMEDY
B.	Faulty high-pressure relief valve	Loss of or lower than normal system pressure in one direction only	1. Switch the two high-pressure relief valves. If the system operates in the direction which it would not operate before, one of the relief valves is in-operative. Repair or replace damaged valve. Retest system.
C.	One check valve faulty	Loss of system pressure in one direction only. Charge pressure might be higher than normal	1. Remove the two check valves located in the pump end cap under the charge pump and check the following: (Refer to *Repair Procedure*.) A. Check to see if poppet or ball is missing. B. Check to see if the valve seat is eroded or deformed. **NOTE** If condition (A) exists, replace the pump. If condition (B) exists, replace both check valves.
D.	Control valve spool jammed or sticking in one direction or misadjusted	Pump will not return to neutral	1. Replace control valve. (Refer to *Repair Procedure*.)
E.	Shuttle valve spool jammed (located in motor manifold)	Loss of or lower than normal system pressure in one direction	1. Remove and replace manifold assembly. (Refer to *Repair Procedure*.)

III. NEUTRAL DIFFICULT OR IMPOSSIBLE TO FIND

	CAUSE	INDICATED BY	REMEDY
A.	Faulty linkage		1. Disconnect control linkage at directional control arm. If system now returns to neutral, the linkage to the control is out of adjustment or binding in some way.

	CAUSE	INDICATED BY	REMEDY
B.	Control valve out of adjustment		1. Replace displacement control valve or readjust according to the following procedure: STEP I: (Refer to Fig. 3.) Remove end play from centering-spring mechanism with locknut (1) loose but holding the centering-spring housing (3). Turn the spring adjusting screw (2) until the screw is just touching the centering-spring washer; thus taking the free end play out of the centering-spring mechanism. This is best done by exerting a light back and forth force on the control-valve spool (6) at the same time the adjusting screw is being turned down. Care must be taken not to compress the centering-spring (4) beyond its installed height. Tighten the locknuts (1) and recheck the spool (6) for end play. STEP II: (Refer to Fig. 3.) Adjust control valve spool for neutral position. Remove the 7/16 x 20 straight thread O-ring plugs on either side of the control valve housing (9) to reveal the servo cylinder porting holes (8). Loosen locknut (7) and adjust the control valve by screwing the centering-spring housing (3) in or out so that the open areas (shaded areas of (10)) between the spools lands and sides of the porting holes are equal. Tighten locknut (7), recheck the open areas and reinstall the two 7/16 x 20 plugs.

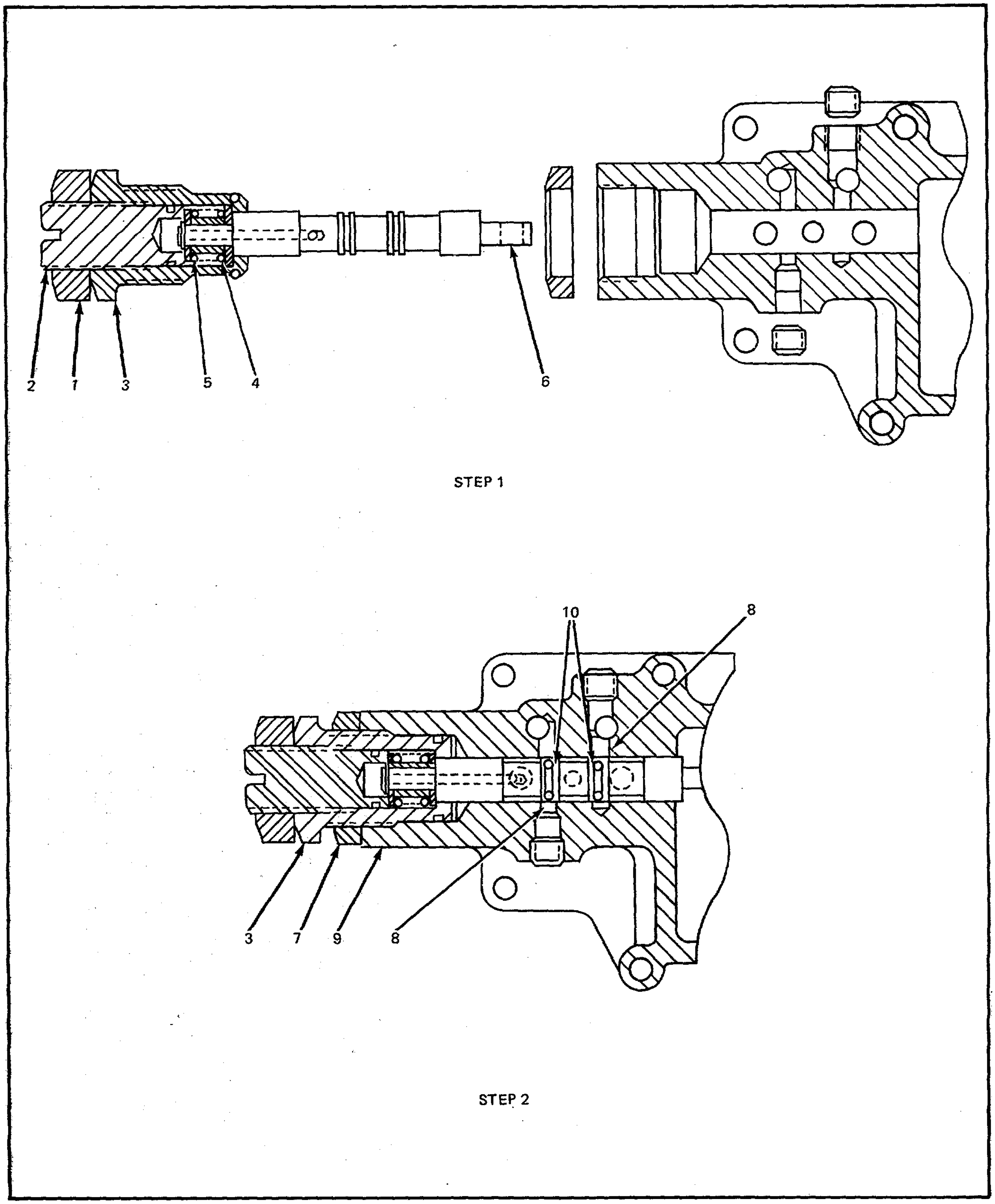


Figure 3.

	CAUSE	INDICATED BY	REMEDY
C.	Servo cylinder out of adjustment		1. Remove pump and return to factory for readjustment. (Refer to *Repair Procedure*, for removal instruction.)

IV. SYSTEM OPERATING HOT (MOTOR CASE TEMPERATURE ABOVE 180°F)

	CAUSE	INDICATED BY	REMEDY
A.	Fluid level low	Low charge pressure	1. Replenish fluid supply.
B.	Fluid cooler clogged		1. Clean cooler air passages.
C.	Fluid in cooler being bypassed (Cooler bypass valve, if used, stuck open)		1. Repair or replace valve.
D.	Clogged filter or suction line	High vacuum and low charge pressure	1. Replace filter; clean or replace suction lines.
E.	Rotary bypass valve, if used, partially open (located on motor manifold)	Slower than normal motor speed Lower than normal or loss of system pressure	1. Close bypass valve.
F.	Excessive internal leakage	Lower than normal system pressure in one or both directions	1. Check the high-pressure relief valves; one may be stuck partially open.
		Lower than normal charge pressure; may drop to or near zero when maximum obtainable system pressure is reached	2. Refer to: System *Will Not Operate In Either Direction, Item G-1.* 3. Replace the pump or motor or both units. (Refer to *Repair Procedure*.)
		Loss of acceleration and power	
G.	Case drain lines improperly plumbed		1. Check plumbing, reinstall to proper arrangement.
H.	Continued operation at high-pressure relief valve setting		1. Consult operator's manual for proper machine operation.

	CAUSE	INDICATED BY	REMEDY
V.	SYSTEM NOISY		
A.	Air in system	Considerable amount of foam in reservoir Low and fluctuating charge pressure Spongy control	1. Check for low fluid level. 2. Check inlet system; filter, suction line, etc. for leaks allowing air to be drawn into system. 3. End of case return within the reservoir not submerged in fluid.
B.	Plumbing not properly insulated		1. Make sure hose or tubing is not touching any metal that can act as a sounding board. 2. Insulate hose and tubing clamps with rubber to absorb noise.

VI. ACCELERATION AND DECELERATION SLUGGISH

	CAUSE	INDICATED BY	REMEDY
A.	Air in system		1. See step V-A.
B.	Control orifice plug partially blocked		1. Remove the bolts that hold the control housing to pump and check the orifice. (Refer to *Repair Procedure*.) **CAUTION** Do not allow O-rings to fall into the pump case. 2. If orifice is clean, remove the charge pump and the plug at the charge pressure gage port and blow clean air through the passage between the charge pump and control orifice port.
C.	Rotary bypass valve, if used, partially open (located on motor manifold)	Lower than normal system pressure	1. Close bypass valve.

	CAUSE	INDICATED BY	REMEDY
D.	Internal wear or damage in pump or motor or both		1. See item I-G.
E.	Engine lugs down		1. Consult vehicle engine manual.

VII. VARIABLE DISPLACEMENT MOTOR WILL NOT CHANGE DISPLACEMENT

	CAUSE	INDICATED BY	REMEDY
A.	Control pressure line from pump to motor not connected		1. Connect line.
B.	Displacement control valve not adjusted properly		1. Replace control valve. (Refer to *Repair Procedure*.)
C.	Plugged orifice in motor control		1. Remove the bolts that hold the housing to motor and check the orifice. **CAUTION** Do not allow the orifice or O-rings to fall into the pump case. (Refer to *Repair Procedure*.)

SYSTEM MAINTENACE

FLUID Generally, a fluid change interval of 2000 hours is adequate with a sealed reservoir system. A more frequent fluid change is required if the fluid has become contaminated by water or other foreign material or has been subjected to abnormal operating conditions.

An open reservoir system with an air-breathing filler cap requires the fluid to be changed every 500 hours.

More specific practices should be developed as a function of vehicle design, applied use and experience in operation. (See *Recommended Fluids*.)

FILTER As a general recommendation, with a sealed reservoir system, the 10-micron inlet filter should be changed each spring or every 500 hours, whichever occurs first. With an open reservoir system utilizing an air-breathing filler cap, the filter should be changed every 500 hours.

RESERVOIR The reservoir should be checked daily for the proper fluid level and the presence of water in the fluid. If fluid must be added to the reservoir, use only filtered or strained fluid. Drain any water as required.

HYDRAULIC LINES AND FITTINGS Visually check daily for any fluid leakage. Tighten, repair or replace as required.

HEAT EXCHANGER The heat exchanger core and cooling fins should be kept clean at all times for maximum cooling and system efficiency. Inspect daily for any external blockage and clean as required.

REPAIR PROCEDURE

REPLACEMENT OF CHARGE PUMP

REMOVAL

1. Remove the line connecting charge pump to reservoir and plug with clean plastic plug to prevent draining of reservoir.

2. Remove the four capscrews.

NOTE

Do not remove the capscrew at the top and bottom of the charge pump, as these hold the charge pump together. (Refer to Fig. 1.)

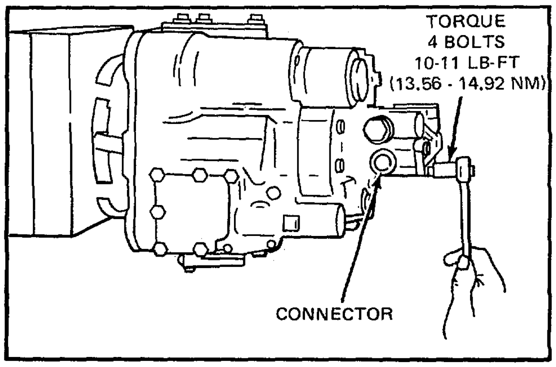


Figure 1.

3. Pull charge pump away from main pump.

NOTE

Do not use sharp tools to pry charge pump from main pump. A scratch on the sealing surface may cause a leak. If charge pump does not pull loose, tap lightly on side of charge pump with plastic hammer to break paint or gasket seal.

INSTALLATION

1. Install a new gasket. Make sure the new gasket is properly installed (refer to Fig. 2). If positioned wrong the relief valve port is covered by the gasket.

2. Line up the drive tang on charge pump shaft with slot in main pump shaft (refer to Fig. 3). The charge pump should assemble freely with main pump freely. Do not force charge pump into position.

3. Tighten the four mounting bolts to 10-1 lb ft (13.56-14.92 Nm) torque.

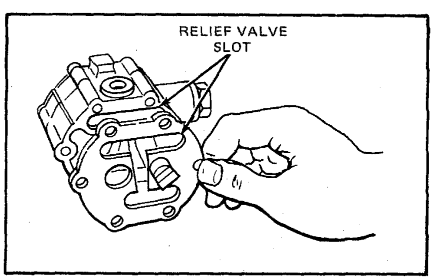


Figure 2.

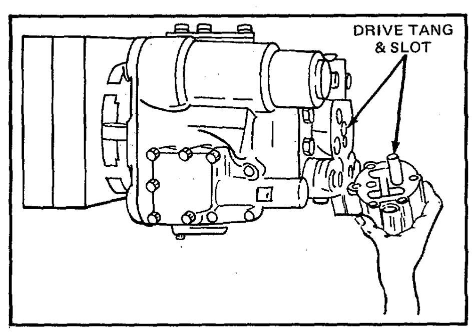


Figure 3.

4. Install connector to charge pump (refer to Fig. 4). Torque 14-20 lb ft (18.98-27.12 Nm).

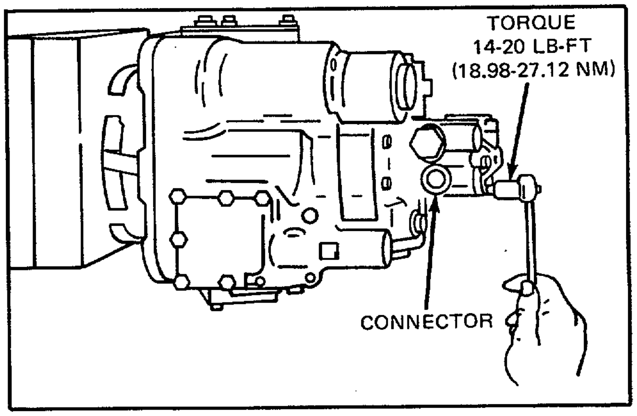


Figure 4.

5. Install line from reservoir to connector on charge pump.

NOTE

Excessive tightening may distort charge pump and cause leaks or malfunction.

6. Check oil level in reservoir.

REPLACEMENT OF CHECK VALVES

REMOVAL

1. Remove charge pump (refer to Installation and Plumbing).
2. Using a drag link, unscrew check valve from end cap (refer to Fig. 5).

NOTE

There are two check valves. It is advisable to replace both check valves when servicing unit (refer to Fig. 6).

INSTALLATION

1. Prior to installation, inspect O-rings for damage (refer to Fig. 7). Apply a light coat of oil.

On 20 through 23 series pumps, tighten check valves to 30-40 lb ft (40.68- 54.24 Nm) torque.

On 24 through 27 series pumps, tighten check valves to 80-90 lb ft (108.48- 122 Nm) torque.

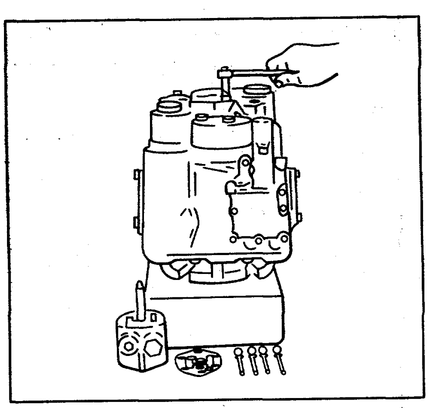


Figure 5.

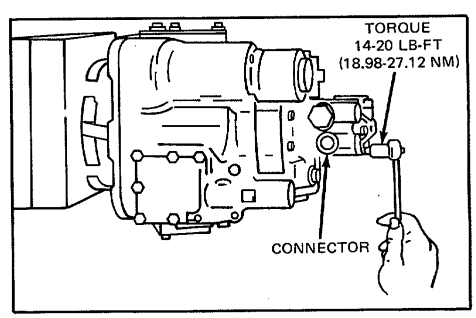


Figure 6.

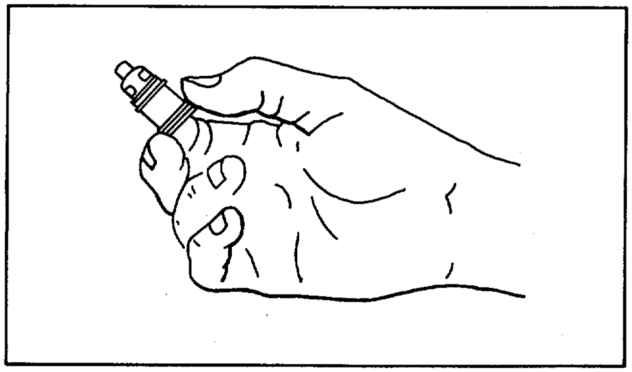


Figure 7.

REMOVAL OF MANIFOLD

REMOVAL

1. Prior to removal of manifold assembly, remove all dirt and clean area where manifold assembly is attached to end cap.

2. Place drain pan under manifold to catch oil.

3. Remove the four corner bolts holding manifold to motor end cap (refer to Fig. 8). Figure 8.

NOTE

The checks must be below the face of the end cap. (Refer to Fig. 5.)

4. Grasp manifold to prevent it from dropping and remove remaining two mounting bolts. (Refer to Fig. 9.) There is no gasket between the manifold and end cap. Sealing is obtained by O-rings and backup rings.

INSTALLATION

1. Use new O-rings and backup rings.

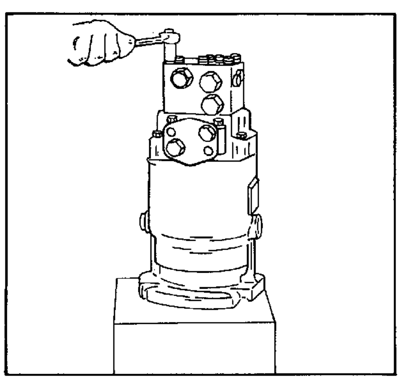


Figure 8.

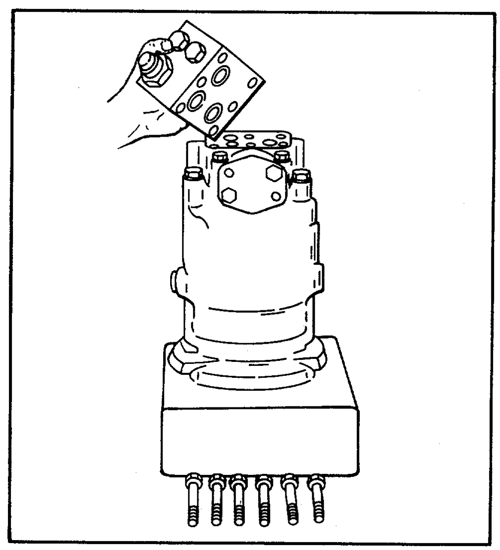


Figure 9.

2. The two grooves side by side re- quire an O-ring and backup ring. The O-ring goes into the groove first. Then install the backup ring on top of the O-ring. The flat side of the back- up ring faces away from the O-ring.
3. The remaining groove requires only an O-ring (refer to Fig. 10).

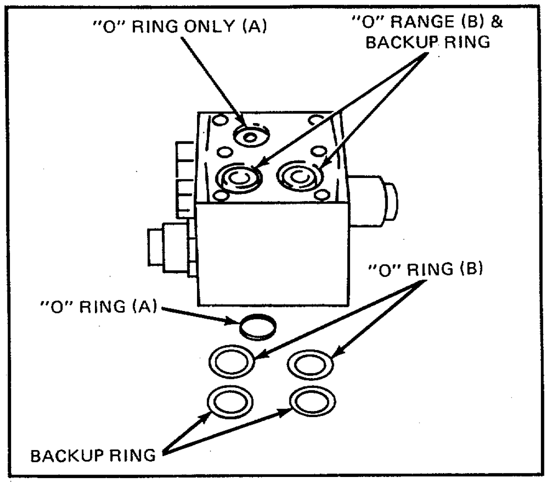


Figure 10.

4. Place manifold against motor end cap. Install bolts, being certain O-rings did not slip from their grooves. Tighten bolts to 19-21 lb ft (27.7628.47 Nm) torque.
5. Check reservoir for oil level.

REPLACEMENT OF HIGH PRESSURE RELIEF VALVES

REMOVAL

1. Apply a wrench on hex portion of valve and unscrew from manifold block (refer to Fig. 11).

NOTE

There are two relief valves in manifold block.

INSTALLATION

1. Prior to installation, inspect O-rings and backup rings for damage.
2. Apply a lubricant to the O-ring and install valve in manifold block (refer to Fig. 12).
3. Tighten valve to 20 lb ft (27.12 Nm) torque.

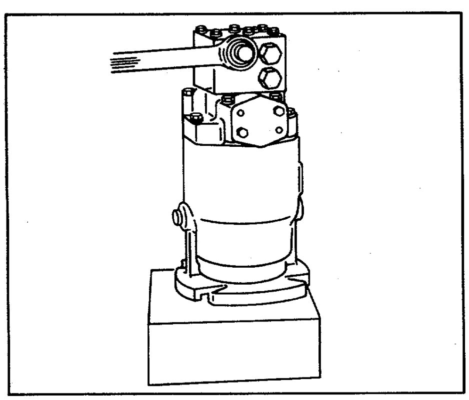


Figure 11.

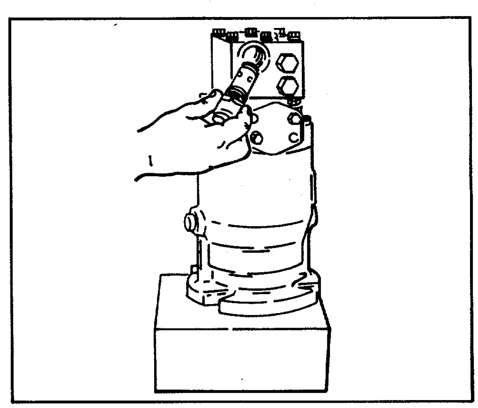


Figure 12.

REPLACEMENT OF DISPLACEMENT CONTROL VALVE

REMOVAL

1. Remove control linkage from displacement control valve assembly.
2. Remove the nine capscrews holding valve to pump housing (refer to Fig. 13).
3. Lift valve away from housing and remove cotter pin and washer. (Refer to Fig. 14.) Remove pin from link in pump.

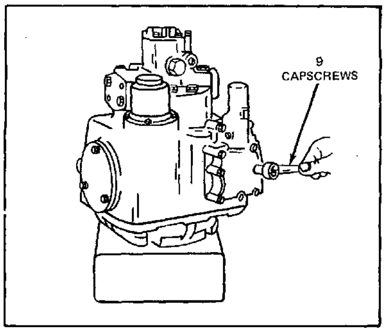


Figure 13.

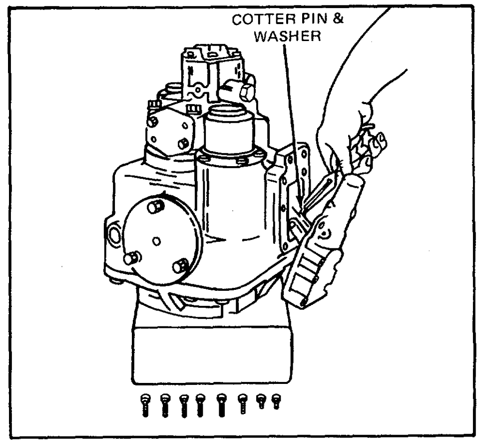


Figure 14.

NOTE
Caution must be exercised to prevent these parts from falling into pump.

4. Remove orifice and O-rings from control valve (refer to Fig. 15).

INSTALLATION

1. Install orifice, tip down, and new O-rings in control valve.
2. Install new gasket on control valve dry.
3. Install pin in control valve links and pump link.
4. Place washer in pin, install cotter pin and spread.

NOTE
Caution should be exercised during installation of these parts to prevent them falling into unit. Lightly coating parts with petroleum jelly (not grease) is advised.

5. Install valve to pump and tighten the nine bolts to 10-11 lb ft (13.5614.92 Nm) torque.

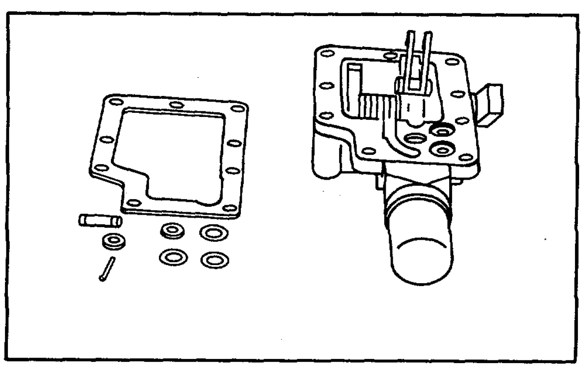


Figure 15.

REPLACEMENT OF MOTOR OR PUMP SHAFT SEAL

REMOVAL

1. Remove unit from installation.
2. Insert Truarc #7 pliers in snap- ring holes, compress ring and roll out (refer to Fig. 16).
3. Remove aluminum seal retainer with screwdriver (refer to Fig. 17).
4. Remove steel stationary seal (this generally comes out with retainer) (refer to Fig. 18).

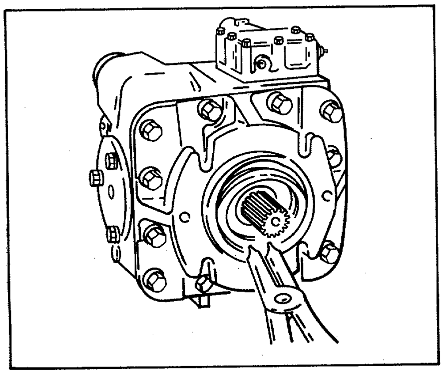


Figure 16.

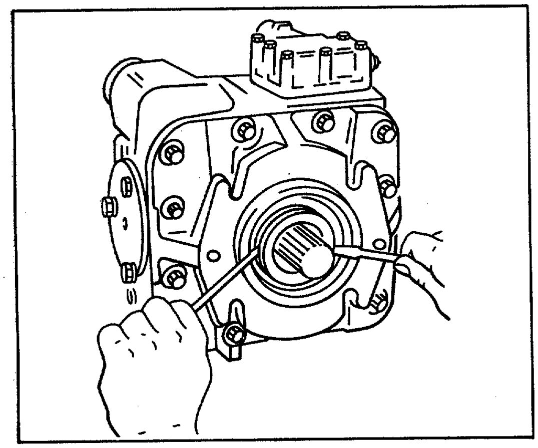


Figure 17.

5. With fingers or two screwdrivers remove bronze rotating part of seal from drive shaft (refer to Fig. 20).
6. Refer to Fig. 19 and account for all the parts shown.

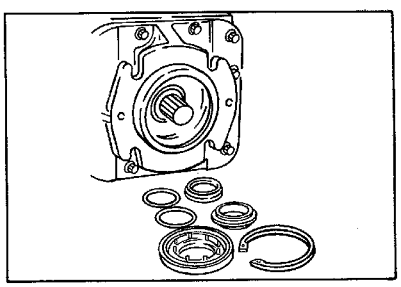


Figure 18.

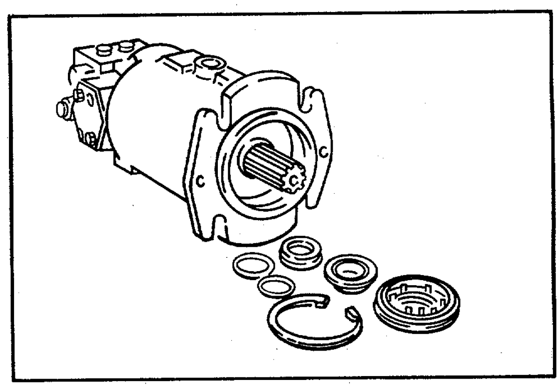


Figure 19.

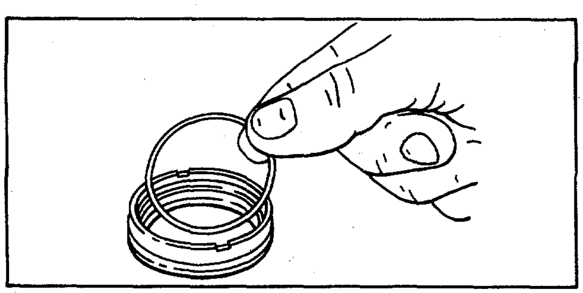


Figure 20.

INSTALLATION

NOTE

Always replace both stationary and rotating parts of seal. Do not mix old and new parts.

1. Wash and clean air dry new seal parts.

2. Install the seal springs into aluminum seal retainer. Install new 0rings dry on stationary steel part of seal and place seal into retainer so notch is located in pin in retainer (refer to Fig. 21).

3. Install large O-ring on O.D. of retainer (refer to Fig. 21).

4. Install new O-ring in I.D. of bronze rotating part of seal (refer to Fig. 20).

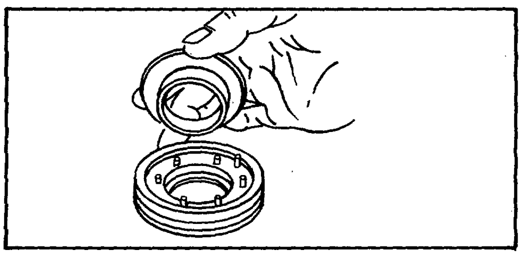


Figure 21.

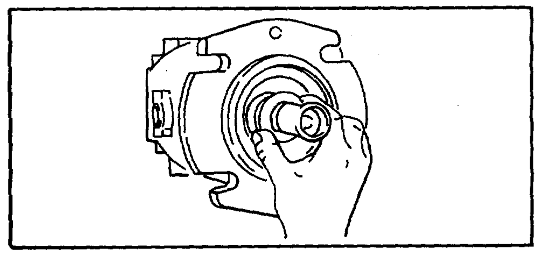


Figure 22.

5. Wrap a piece of plastic around drive shaft and slide rotating bronze part over shaft making sure it is seated. Do not press on seal surface (refer to Fig. 22).

6. Install stationary seal and retainer into place and press retainer in so snapring groove is open (refer to Fig. 23).

7. Close snapring with pliers. Install snapring with tapered edge out.

8. For ease of installation start snapring in groove with side opposite snapring holes (refer to Fig. 24).

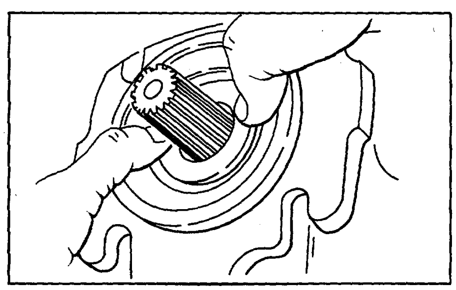


Figure 23.

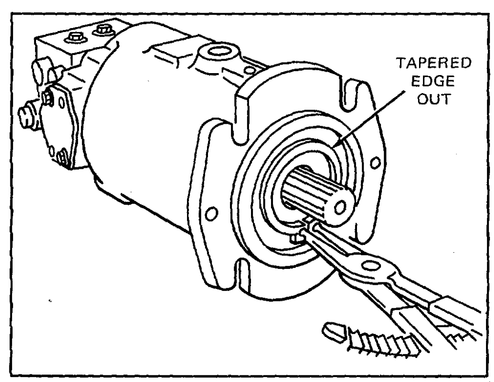


Figure 24.

REPLACEMENT OF PRESSURE OVERRIDE VALVE AND DISPLACEMENT CONTROL VALVE

REMOVAL

1. Remove control linkage from displacement control valve assembly.
2. Remove the two hoses connected between the pump end cap and pressure override valve (refer to Fig. 25).
3. Remove the six bolts holding the P.O.R. valve to the displacement control valve.
4. Remove O-rings from P.O.R. valve (refer to Fig. 26).
5. Remove the remaining three bolts in the displacement control. Lift valve away from housing and remove cotter pin and washer (refer to Fig. 14 and Fig. 27). Remove pin from link in pump.

NOTE

Caution must be exercised to prevent these parts from falling into pump.

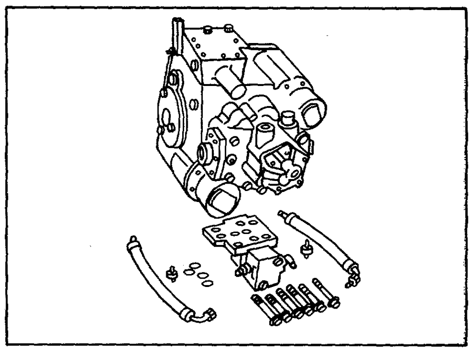


Figure 26.

6. Remove orifice and O-rings from control valve (refer to Fig. 27).

INSTALLATION

1. Install orifice, tip down and new O-rings in control valve.
2. Install new gasket on control valve dry.

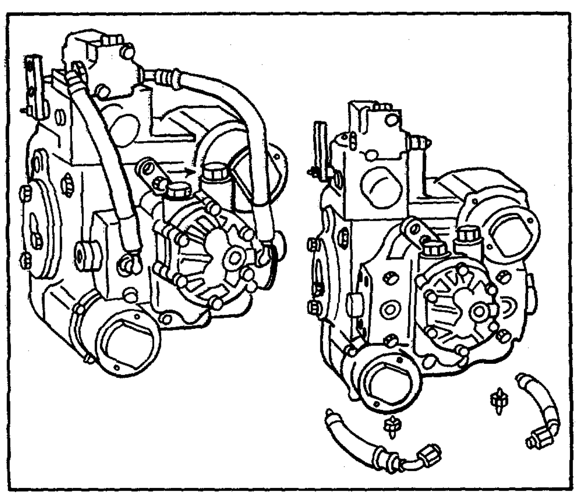


Figure 25.

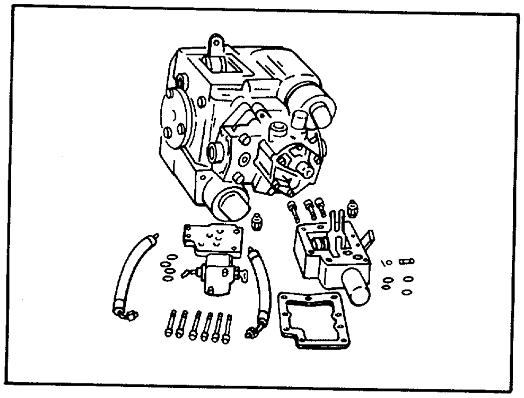


Figure 27.

3. Install pin in control valve links and pump link.
4. Place washer in pin, install new cotter pin and spread.

REPLACEMENT OF ROTARY BYPASS VALVE AND MANIFOLD ASSEMBLY

REMOVAL

1. Prior to removal of rotary bypass valve and manifold assembly, remove all dirt and clean area where bypass and manifold assembly is attached to end cap.
2. Place drain pan under manifold to catch oil.
3. Grasp the bypass valve to prevent it from dropping. Remove the four bolts holding bypass valve to manifold. There is no gasket between bypass valve and manifold assembly. Sealing is obtained by O-rings and backup rings (refer to Fig. 28).
4. Grasp manifold to prevent it from dropping and remove remaining two mounting bolts (refer to Fig. 29).

NOTE

Caution should be exercised during installation of these parts to prevent them from falling into unit. Lightly coating parts with petroleum jelly (not grease) is advised.

5. Install valves to pump using the three shortest bolts in the back holes (refer to Fig. 26).
6. Install new O-rings in P.O.R. valve.
7. Install P.O.R. to displacement control valve with remaining six bolts and tighten all nine bolts to 10-11 lb ft (13.56-14.92 Nm) torque.
8. Install two pressure override hoses to the valve and pump end cap. There is no gasket between manifold and end cap. Sealing is obtained by O-rings and backup rings.

INSTALLATION

1. Use new O-rings and backup rings.
2. The two grooves side by side in manifold require an O-ring and backup ring. The O-ring goes into the groove first. Then install the backup ring on top of the O-ring. The flat side of the backup ring faces away from the O-ring.
3. The remaining groove requires only an O-ring (refer to Fig. 30).
4. Place manifold against motor end cap. Install the two shortest bolts in the bottom two holes, being certain O-rings did not slip from their grooves.

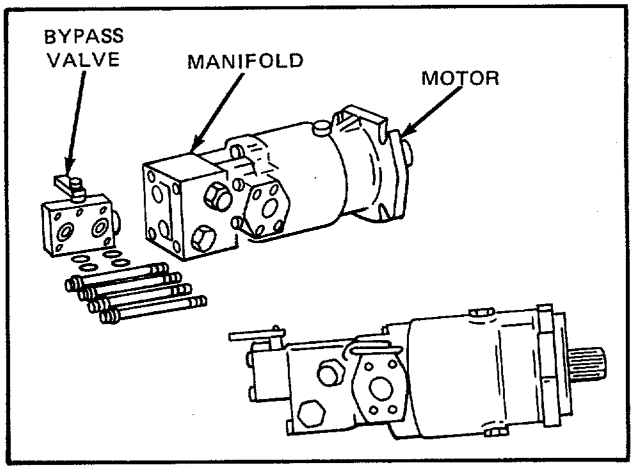


Figure 28.

5. The two grooves side by side in the bypass valve require an O-ring and a backup ring. Install in the same manner as motor manifold.

6. Place bypass valve against manifold. Install remaining bolts being certain O-rings did not slip from their grooves. Tighten bolts to 19-21 lb ft (27.76-28.47 Nm) torque.

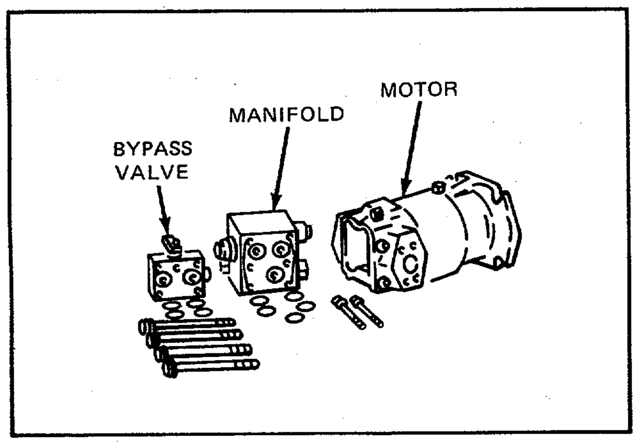


Figure 29.

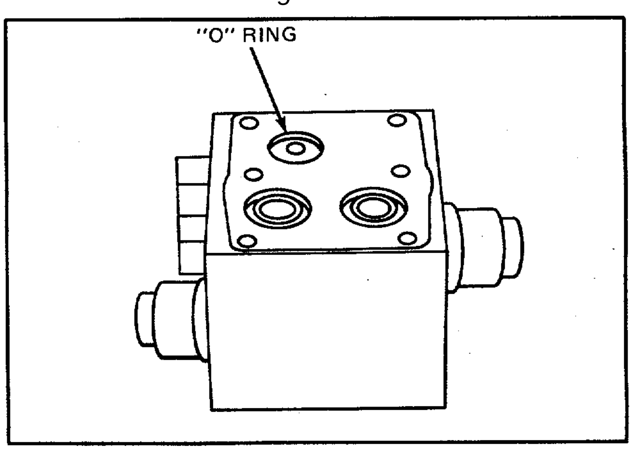


Figure 30.

FIXED DISPLACEMENT MOTOR REPAIR

The areas of repair indicated may be serviced, following the procedures in this manual, without voiding the warranty.

Installation torque values for cap-screws are given in the table at the end of this manual.

NOTE

System pressure gauge port is located on side opposite the corresponding high pressure relief valve cartridge.

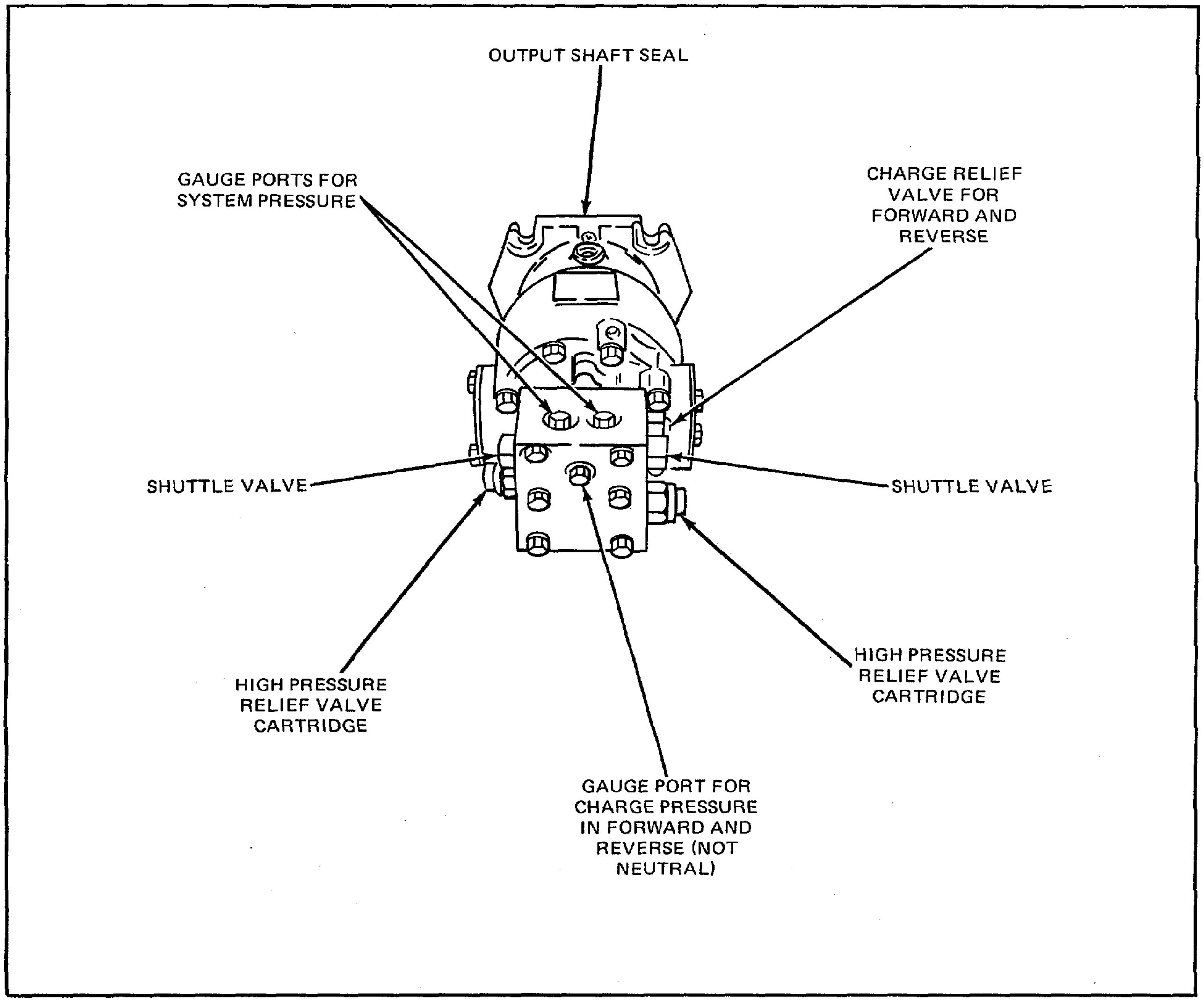


Figure 1.

Minor Repairs

Special Tools (refer to Fig. 2).

The following tools are required but not normally carried:

1. Truarc Retaining Ring Pliers (#7)
2. Torque Wrench

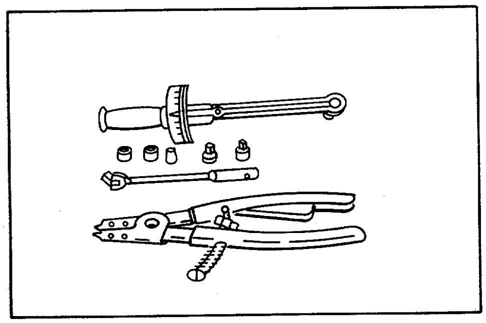


Figure 2.

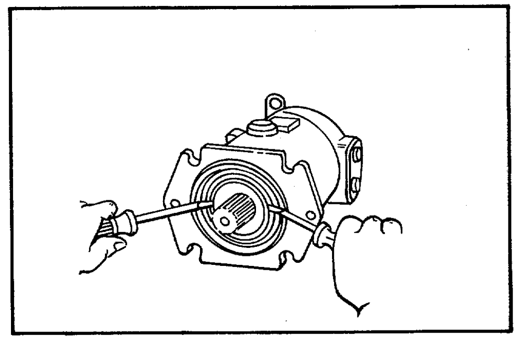


Figure 4.

It is recommended that all shaft seal parts be replaced. If parts are to be reused, they must be protected from being damaged by the shaft during removal.

Remove the large retaining ring located on the shaft end of the motor. Remove the side opposite the tangs from the groove first (refer to Fig. 3).

The aluminum housing is removed next. It is held in place by the friction of the O-ring on its O.D. Pry the housing toward the end of the shaft until the O-ring is free (refer to Fig. 4).

Remove the housing from the shaft. This part is actually an assembly that is being held together by the friction of an internal O-ring. It will normally remain assembled until physically separated (refer to Fig. 5).

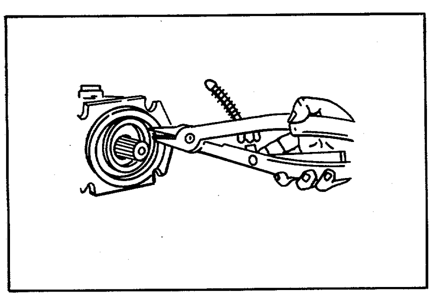


Figure 3.

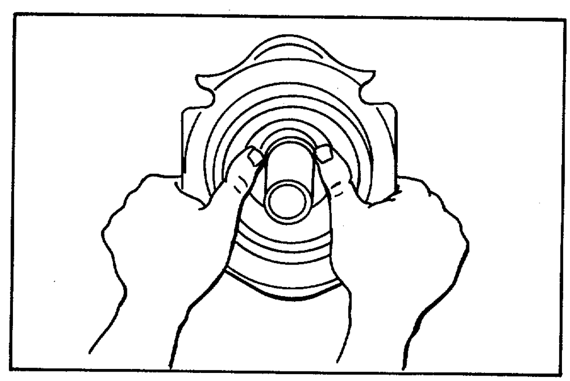


Figure 5.

The bronze sealing ring is also held in place by internal O-ring friction. Work this part free and carefully slide over the shaft (refer to Fig. 6).

CAUTION

This part is easily damaged and care must be exercised when handling.

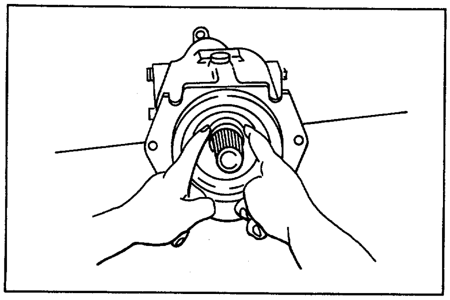


Figure 6.

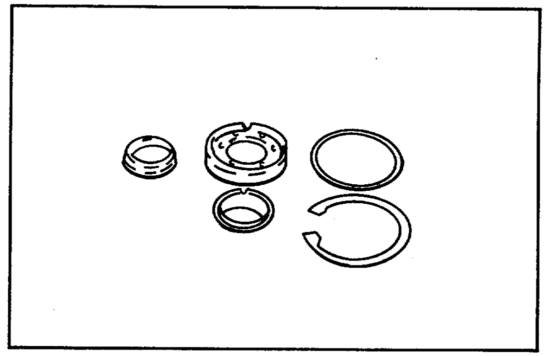


Figure 8.

All of the shaft seal parts, which are included in the shaft seal kit, have now been removed. Each part should be inspected separately if the seal is to be reused. It is recommended that this entire shaft seal be replaced (refer to Fig. 7).

Prior to assembly, place one O-ring in the I.D. of the bronze sealing ring and one O-ring in the I.D. of the aluminum housing. Place the six springs in the cavities in the housing. Care must be used to protect the parts from damage by the shaft during assembly (refer to Fig. 8).

Slide the sealing ring over the shaft and onto the shaft pilot diameter with the O-ring facing the motor. Work the ring into place using hand force only (refer to Fig. 9).

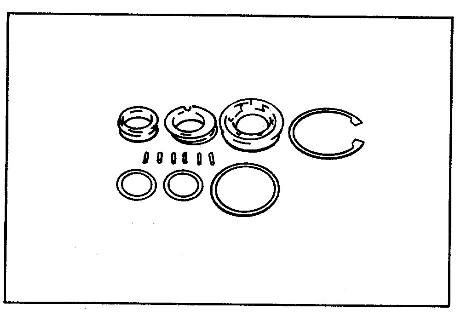


Figure 8.

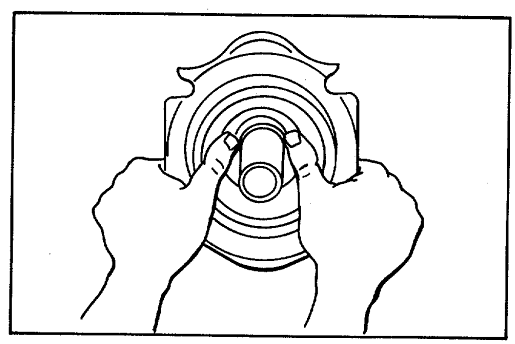


Figure 9.

Insert the stationary seal pilot into the aluminum housing, locating the notch in the stationary seal over the pin in the housing (refer to Fig. 10).

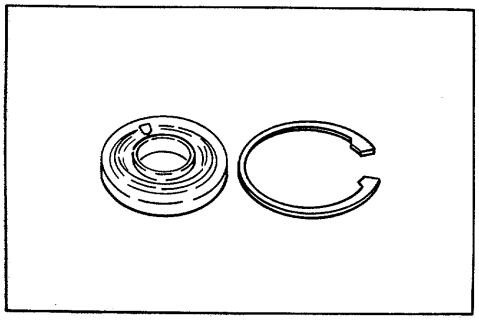


Figure 10.

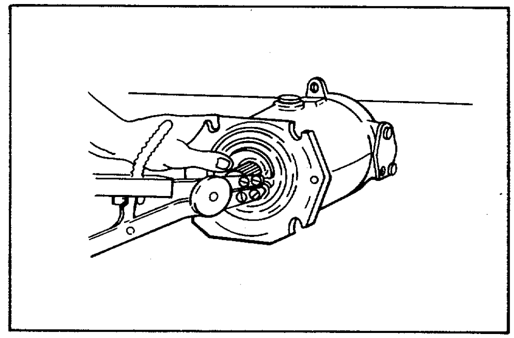


Figure 12.

Install the O-ring on the O.D. of the housing, then slide it into place against the bronze sealing ring. Since this is a spring loaded assembly, it may be necessary to push against the aluminum housing to expose the retaining ring groove (refer to Fig. 11).

Install the retaining ring with the beveled side out, putting the side opposite the tangs into the groove first. Be certain that the retaining ring has snapped into its groove completely (refer to Fig. 12).

The high-pressure relief valves are cartridges that are removed by unscrewing them from the manifold. These valves are factory set and the first two numbers of the pressure setting are stamped on the end of the valve. These valves are interchangeable and can be installed in either side of the manifold, providing the pressure settings are the same (refer to Fig. 13).

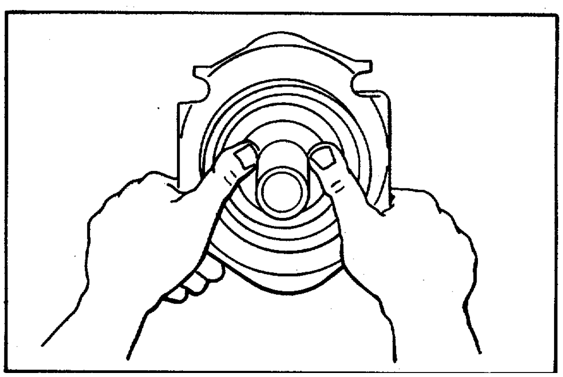


Figure 11.

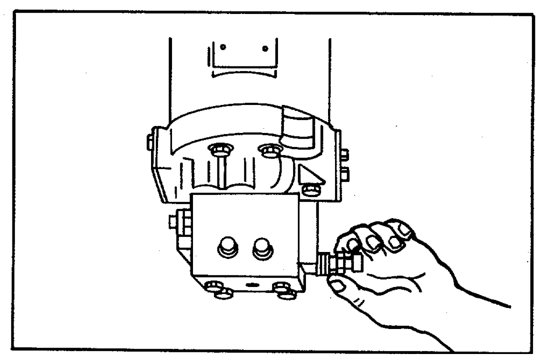


Figure 13.

MOTOR REPAIR HYDROSTATIC SYSTEM

To repair the shuttle valve, remove both hex plugs, springs, washers, and spool from the manifold. These parts are interchangeable and can be installed on either side of the manifold. The spool and manifold are a select fit and must be replaced together. To install, slide the spool into the bore, place a washer on each end, then slide both springs in place. Install the hex plugs and tighten (refer to Fig. 14).

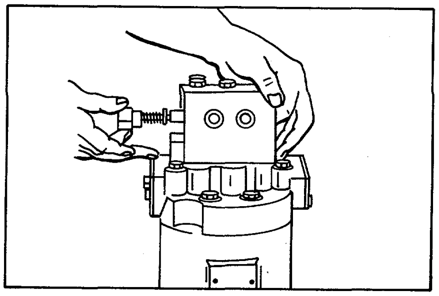


Figure 14.

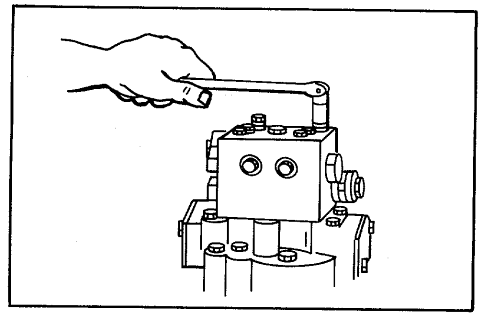


Figure 16.

To repair the charge relief valve, re- move the hex plug, spring and poppet. Remove the shims from the counterbore of the hex plug. Do not alter these shims unless new parts are used, in which case the valve must be re-shimmed to the proper setting. To reinstall, insert the poppet, spring, and plug, being certain the shims are in place (refer to Fig. 15).

The valve manifold assembly can be removed from the motor and replaced in its entirety. The following procedure shows removal of the entire manifold from the motor before performing further disassembly (refer to Fig. 16).

Remove the six hex capscrews and lift the manifold off the motor end cap. The three ports are sealed with O-rings and the two adjacent ports also have backup rings on top of the O-rings. These are rectangular in cross section and slightly cupped on one side where they mate with the O-rings (refer to Fig. 17).

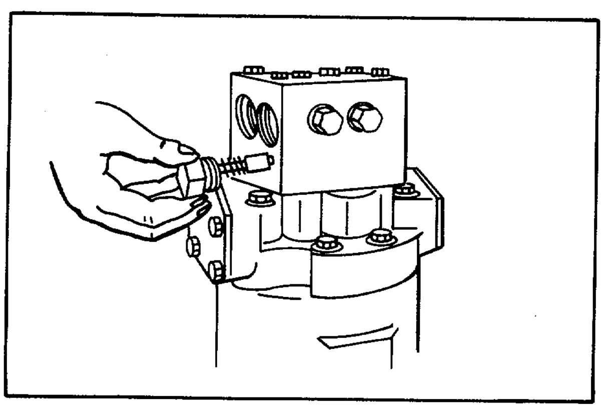


Figure 16.

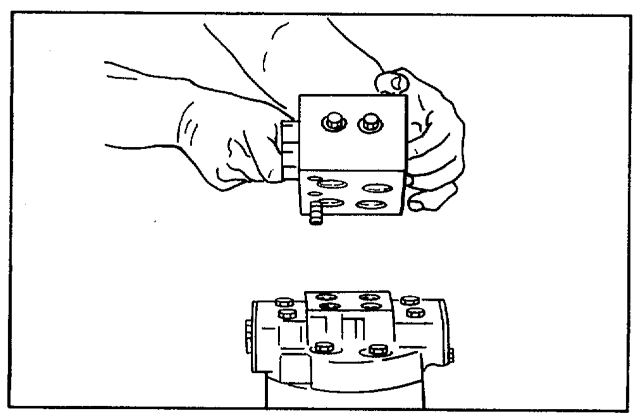


Figure 17.

The manifold assembly contains the following valves (refer to Fig. 18).

High-Pressure Relief Valve Cartridges
Shuttle Valve
Charge Relief Valve

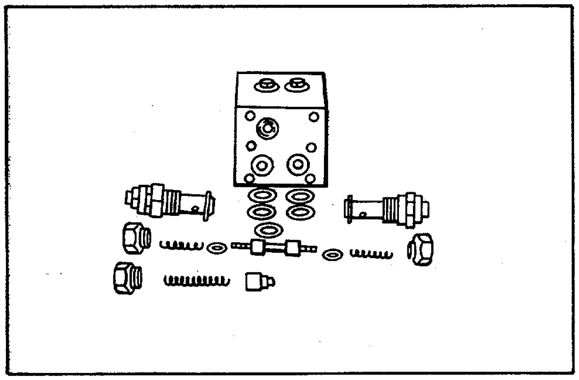


Figure 18.

The O-ring should be placed in the port with the full counterbore. The O-rings and backup rings fit in the ports with the machined grooves. The O-ring should be installed first and then the backup ring (refer to Fig. 19).

When installing the manifold on the end cap be certain the backup rings are properly installed and do not slip out of the grooves (refer to Fig. 20).

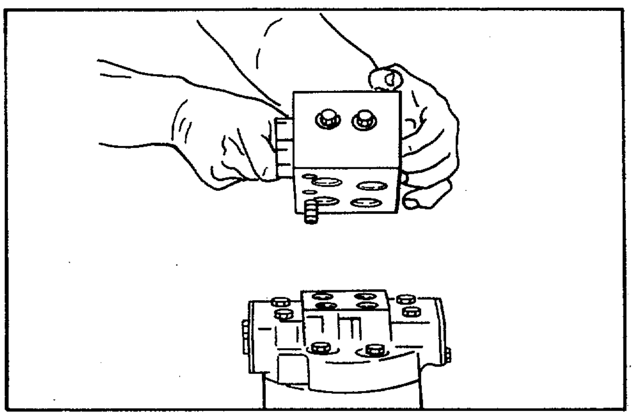


Figure 19.

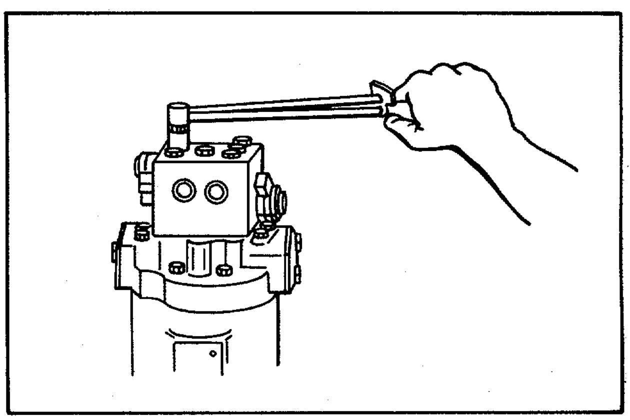


Figure 20.

Major Repairs

Special Tools (refer to Fig. 1).

The following tools are required but not normally carried:

1. Waldes Truarc #7 Retaining Ring Pliers
2. Torque Wrench
3. Tapered Bearing Puller
   Ref. Snap On Part Numbers
   Puller Bar CG350
   20-23 Series: Separator CJ950
   24-28 Series: Separator CJ951

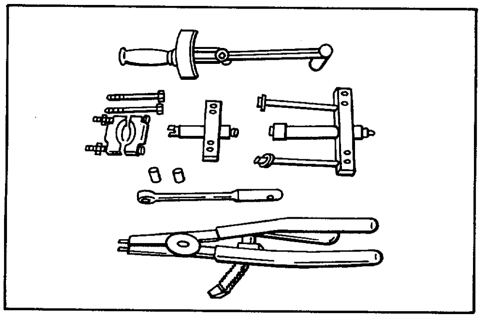


Figure 1.

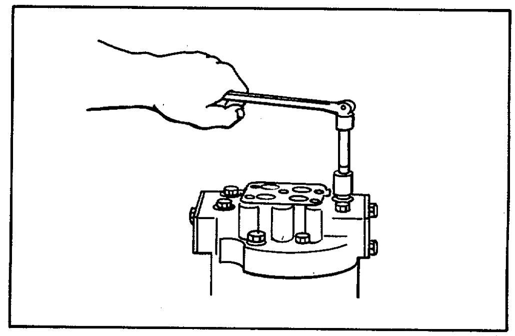


Figure 3.

Remove the shaft seal (refer to Fig. 2), as outlined under Minor Repair Procedures. The shaft seal must be removed before end capscrews are loosened to prevent the seal being damaged.

CAUTION

The end capscrews should not be loosened until the shaft seal has been removed.

Remove the valve manifold assembly as outlined under Minor Repair Procedures.

Remove all but two of the hex head screws holding the end cap to the housing (refer to Fig. 3).

There is an internal spring loading on the end cap and as the last two screws are loosened, it should begin to separate from the housing. Loosen these screws alternately until the end cap has fully separated from the housing, then remove the screws entirely (refer to Fig. 4).

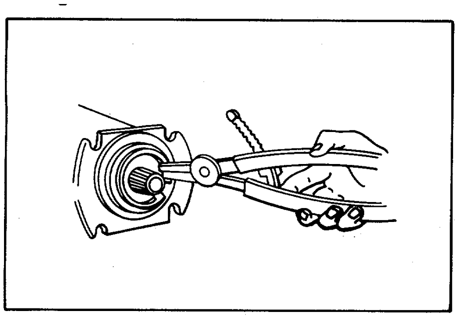


Figure 2.

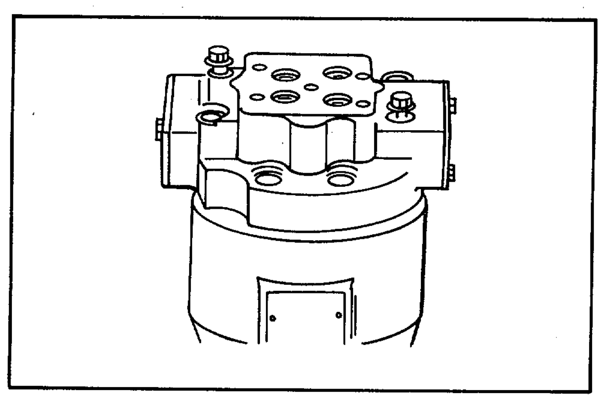


Figure 4.

The end cap can now be lifted off the motor; however, be certain that the valve plate does not fall and become damaged. If the valve plate tends to lift off with the end cap, hold it in place on the end cap and remove both parts together. If the valve plate remains on the bearing plate, remove it at this time (refer to Fig. 5).

CAUTION

All surfaces exposed are critical and caution must be used to avoid damage.

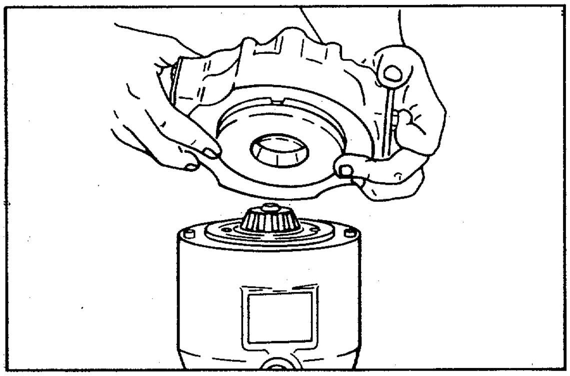


Figure 5.

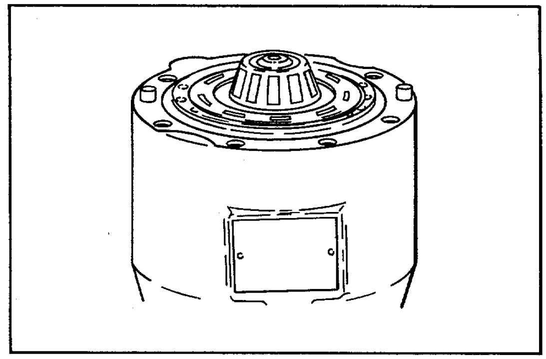


Figure 7.

The end cap is actually an assembly consisting of a tapered bearing race (which is a slip fit in the end cap) and the valve plate locating pin. These parts should be removed from the end cap. There may or may not be a shim located under the bearing race which should be removed (refer to Fig. 6).

Remove the bronze bearing plate and pilot ring from the cylinder block (refer to Fig. 7).

If the pilot ring remains with the bearing plate, remove it at this time (refer to Fig. 8).

Note that the valve plate has four tapered slots, two at the top and two at the bottom. These four slots identify it as a motor valve plate and it is not interchangeable with the pump valve plate (refer to Fig. 9).

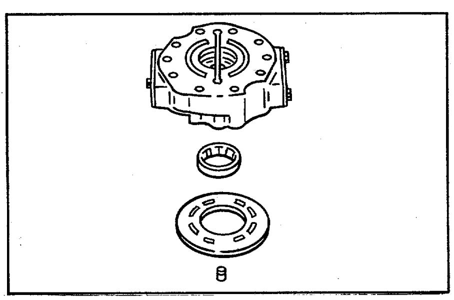


Figure 6.

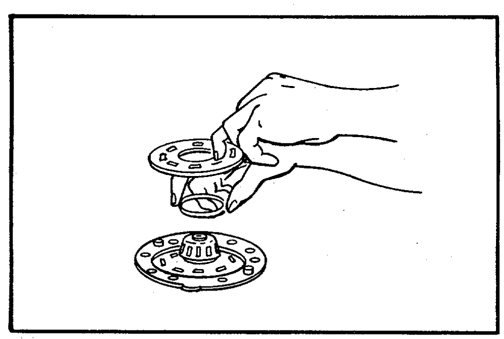


Figure 8.

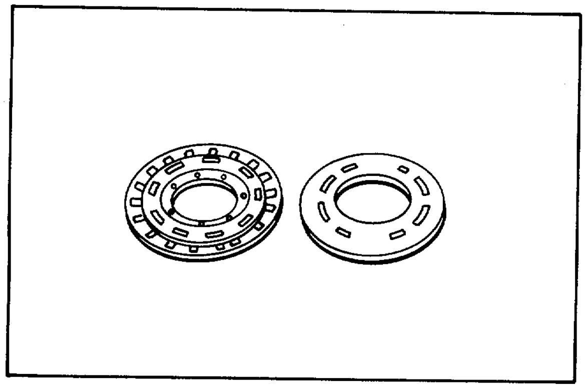


Figure 9.

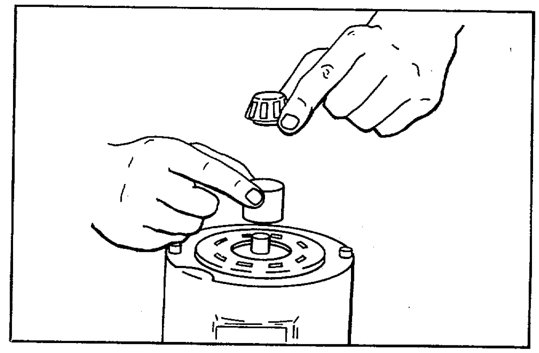


Figure 11.

The tapered bearing must now be removed from the shaft. A bearing puller should be used that will pull against the inner race of the bearing. Protect the cylinder block face during this operation (refer to Fig. 10).

After removal of the bearing, slip the spacer out of the bore in the cylinder block (refer to Fig. 11).

Place the motor in a horizontal position. Slide the cylinder block assembly off the shaft while holding the external end of the shaft (refer to Fig. 12).

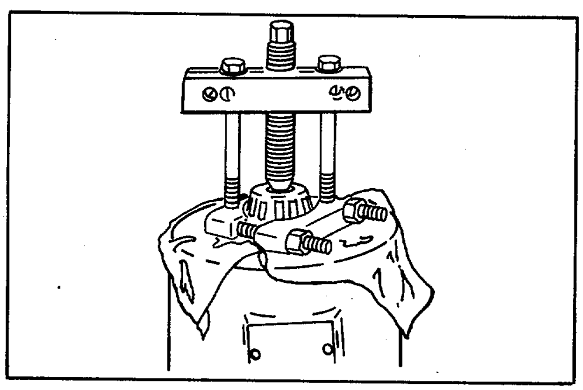


Figure 10.

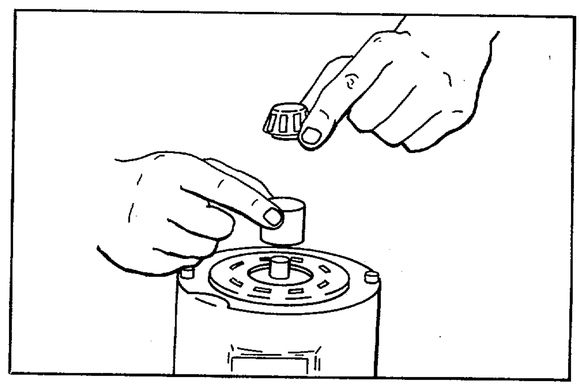


Figure 12.

The cylinder block assembly usually comes out in one piece; however, some of the parts can separate. This does not present a problem as these parts can be reassembled later (refer to Fig. 13).

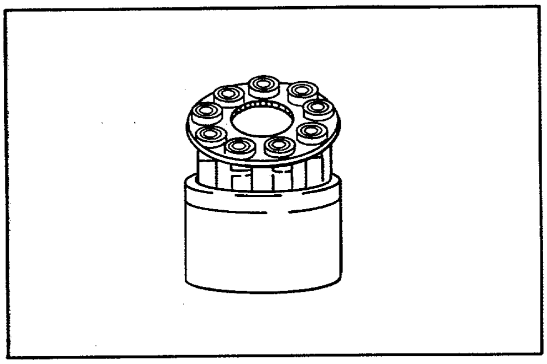


Figure 13.

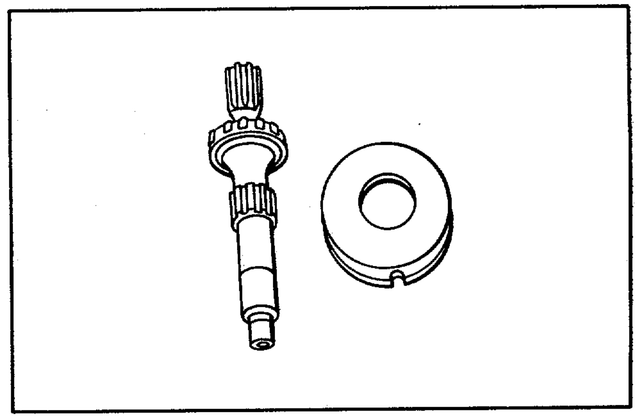


Figure 14.

The swashplate has a notch which locates over a pin in the housing to prevent improper assembly; however, mark the housing for proper orientation of the swashplate during reassembly (refer to Fig. 14).

The fixed swashplate and shaft assembly can now be removed by grasping the shaft and lifting both parts out of the housing (refer to Fig. 14).

The tapered bearing can be pressed off the shaft if required. Be careful not to damage the seal diameter of the shaft while removing the bearing (refer to Figs. 15 and 16). The bearing race is press fit in the housing. If any of the following parts are replaced, the shaft end play must be checked:

Drive Shaft

Bearings

End Cap

Housing

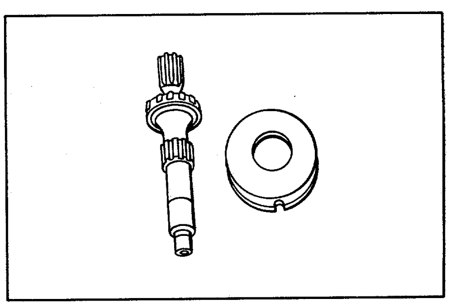


Figure 15.

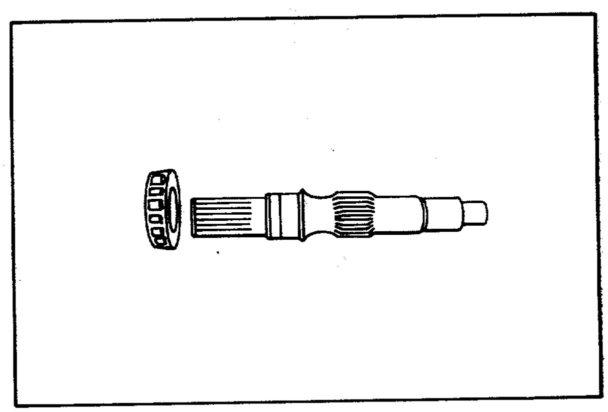


Figure 16.

To check the shaft end play, assemble the shaft and bearings, housing, end cap and gasket (refer to Fig. 17). The shaft end play should be from 0.006 inch to 0.016 inch. If adjustment is necessary, a shim can be placed under the bearing race in the end cap.

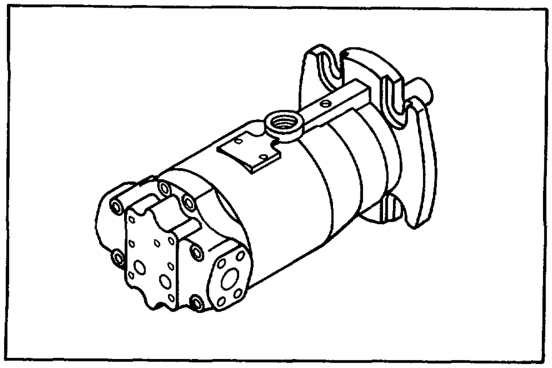


Figure 17.

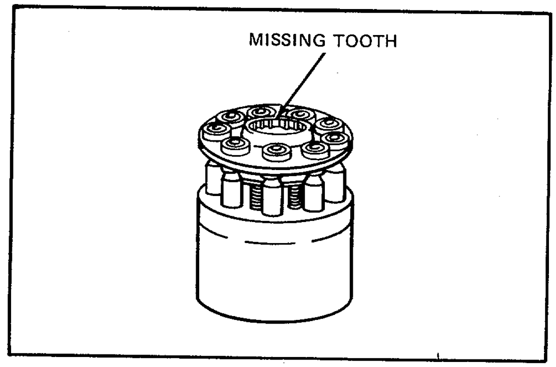


Figure 19.

Place the fixed swashplate over the shaft-bearing assembly and place into housing locating the notch in the swashplate on the pin in the housing (refer to Fig. 18).

The cylinder block should be installed next. It is necessary to check the alignment of certain parts. There is no special relationship of pistons, bores, springs, etc.; however, the alignment of the ball guide and cylinder block splines is critical. The undersized tooth in the spline of the cylinder block must line up with the missing tooth in the ball guide spline. These in turn line up with a missing tooth on the shaft spline. The hole for the bearing plate locating pin in the cylinder block face is in line with the undersize tooth in the cylinder block and provides an assembly guide (refer to Figs. 19 and 20).

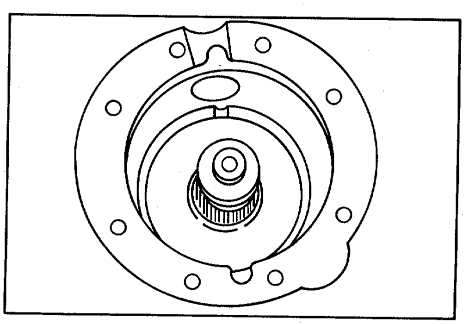


Figure 18.

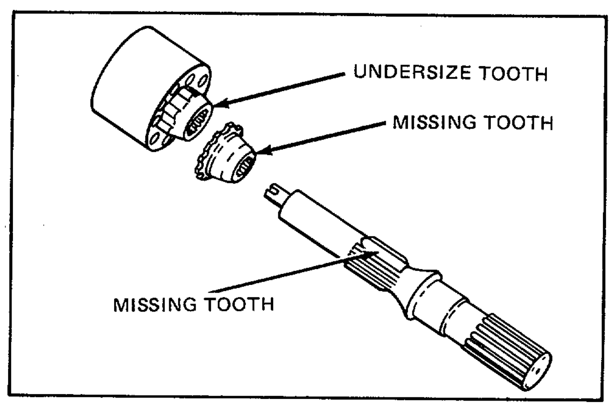


Figure 20.

Lubricate the swashplate, slippers, pistons, and bores with clean hydraulic oil. Hold the shaft on the external end, align the missing shaft tooth with the missing ball guide tooth using the locating pinhole as a guide. Slide the cylinder block assembly onto shaft and against swashplate face. When properly installed, a spring load can be felt when pushing against the cylinder block (refer to Fig. 21).

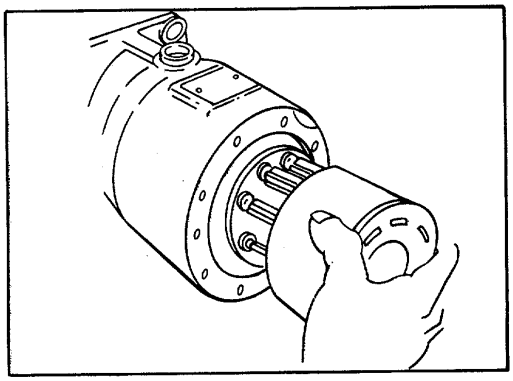


Figure 21.

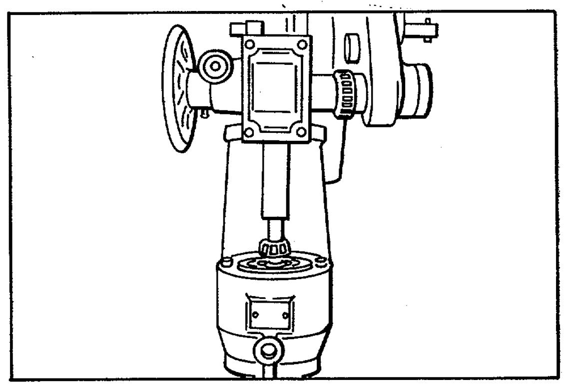


Figure 23.

Set the motor vertically and install the spacer in the center bore of the cylinder block (refer to Fig. 22).

The tapered bearing should be installed with an arbor type press for the most satisfactory results. This bearing cannot be driven onto the shaft due to the internal spring loading of the cylinder block and shaft. Press on the inner race of the bearing and use care not to damage roller cage (refer to Fig. 23).

An alternate method of installing this bearing is to use the bearing puller bar and press the bearing onto the shaft with the center screw of the puller bar. A spacer must be used between the center screw and the bearing. The bearing must be pressed on until it rests on the shoulder of the shaft to insure adequate bearing clearance (refer to Fig. 24).

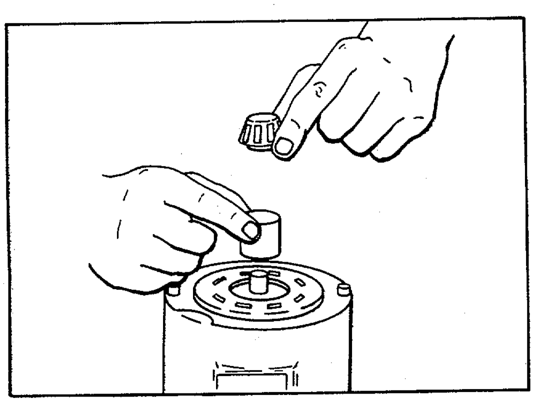


Figure 22.

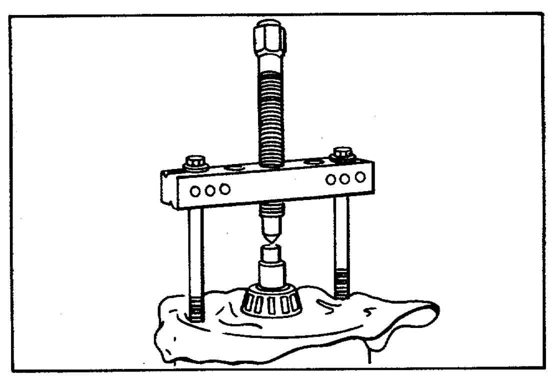


Figure 24.

Install the pilot ring and the locating pin in the cylinder block (refer to Fig. 25).

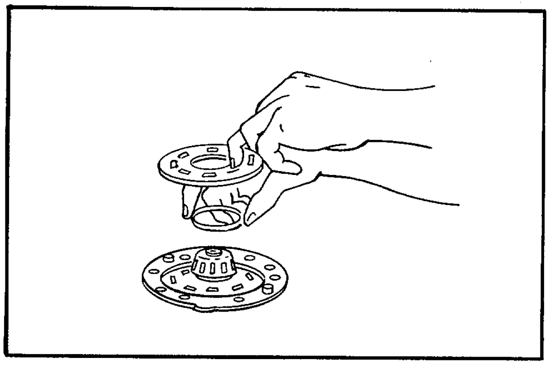


Figure 25.

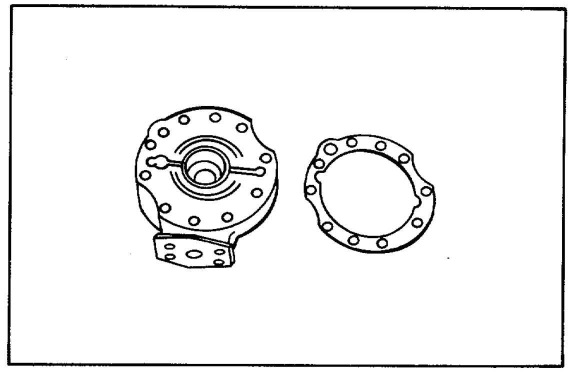


Figure 27.

Install the bearing plate so that the milled slot locates over the pin and the pilot ring fits in the center bore of the cylinder block. After installation lubricate the exposed surfaces with clean hydraulic oil (refer to Fig. 26).

Assemble the bearing race shim (if required) and locating pin in the end cap. Lubricate the end cap face with clean hydraulic oil. Install the valve plate so that the milled slot locates over the pin and the center bore fits over the protruding bearing race.

Check the valve plate to be certain it is a motor valve plate (has 4 tapered slots) (refer to Fig. 27).

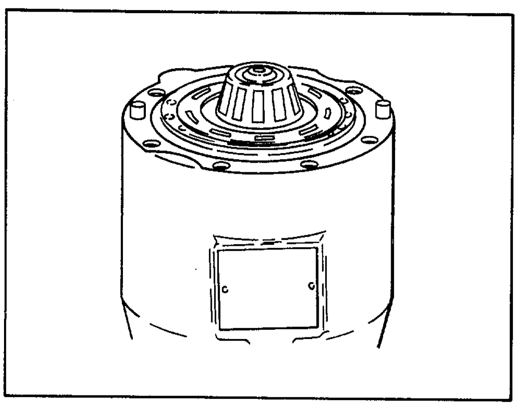


Figure 26.

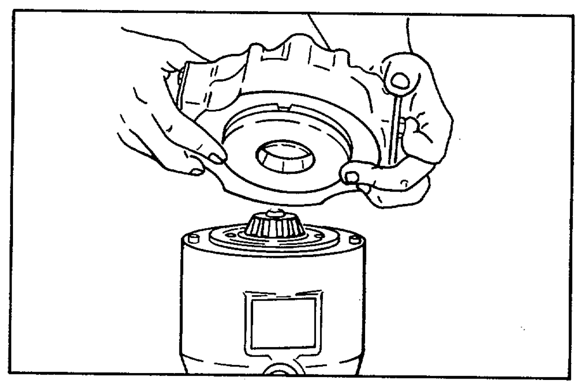


Figure 28.

Place the end cap gasket on the housing, being certain the locating pins are in place, then install the end cap and valve plate. Hold the valve plate so it does not drop off during assembly. The end cap and gasket will only align with housing mounting holes in one position (refer to Fig. 28).

Install two end capscrews and alternately tighten them until the internal spring has compressed far enough for the end cap to rest on the housing. Install the remaining screws (refer to Fig. 29).

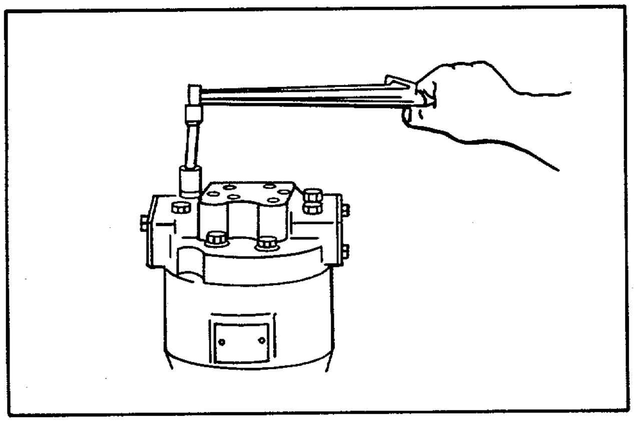


Figure 29.

Install the shaft seal (refer to Fig. 30), and valve manifold as outlined under Minor Repair Procedures.

Fill the motor housing with clean hydraulic oil.

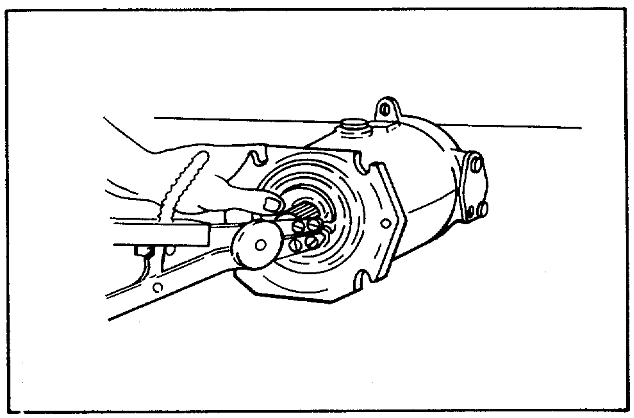


Figure 30.

MOTOR PARTS IDENTIFICATION

GENERAL PARTS LIST

NO./LTR.	DESCRIPTION	QTY.
A	Valve manifold kit	1
B	Cylinder block kit	1
C	Shaft seal kit	1
7	Screw-hex hd cap	4
8	Screw-hex hd cap	4
9	Washer-plain	8
10	End	1
11	Shim-bearing	AS REQ'D
12	Gasket-end cap	1
13	Bearing kit-rear	1
14	Pin-locating	1
15	Valve plate	1
29	Swashplate-fixed	1
30	Shaft	1
31	Bearing kit-front	1
32	Pin	2
33	Plug-hex hd	1
34	O-ring	1
35	Housing	1

This list is for identification of parts only. Specific model and part numbers are necessary to order replacement parts. For part numbers consult the Parts List for the specific model number.

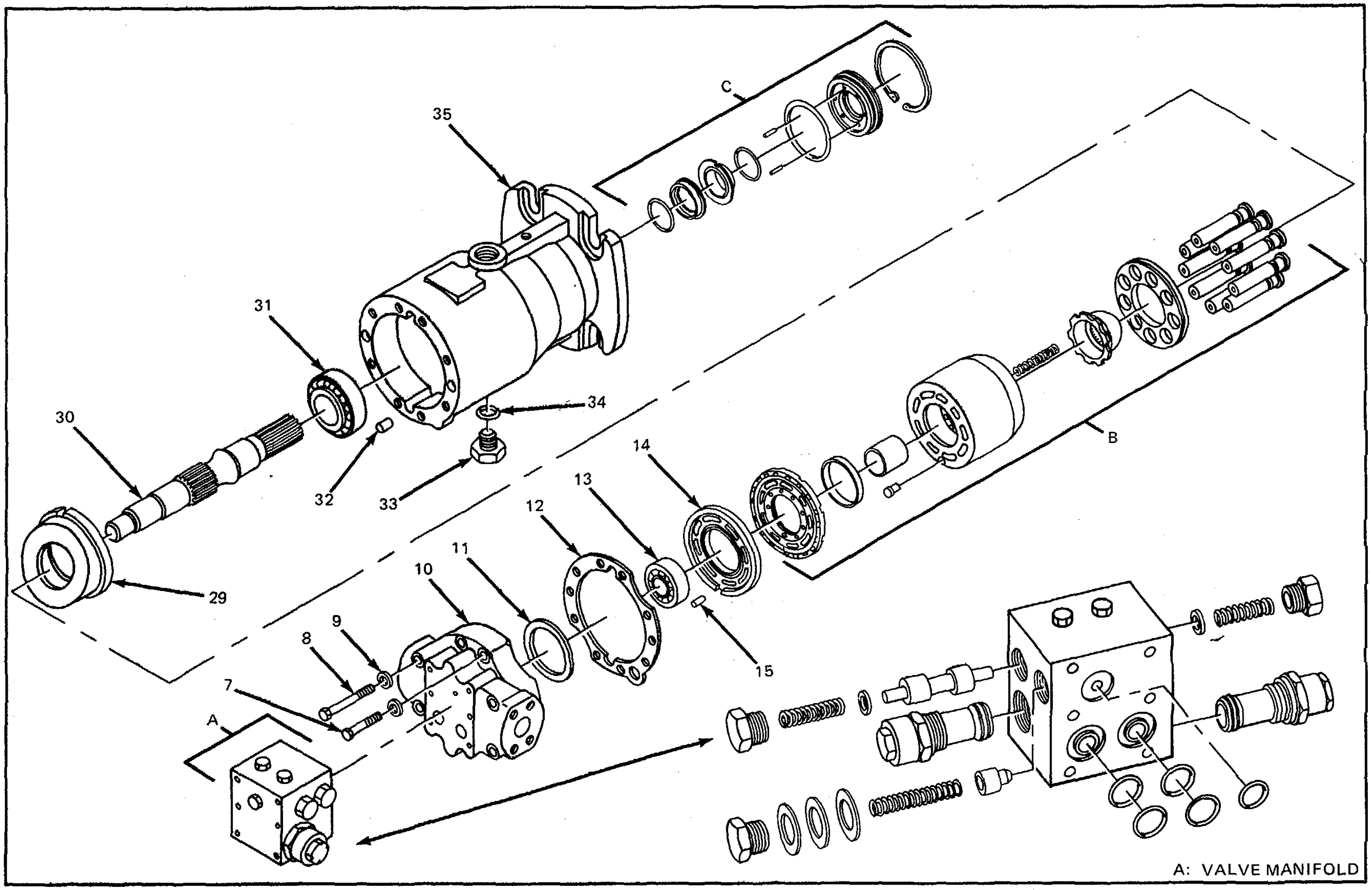


Figure 31. Fixed Displacement Motor

PUMP REPAIR

The areas of repair indicated may be serviced, following the procedures in this manual, without voiding the warranty.

Installation torque values for capscrews and other parts are given in the table at the end of this manual.

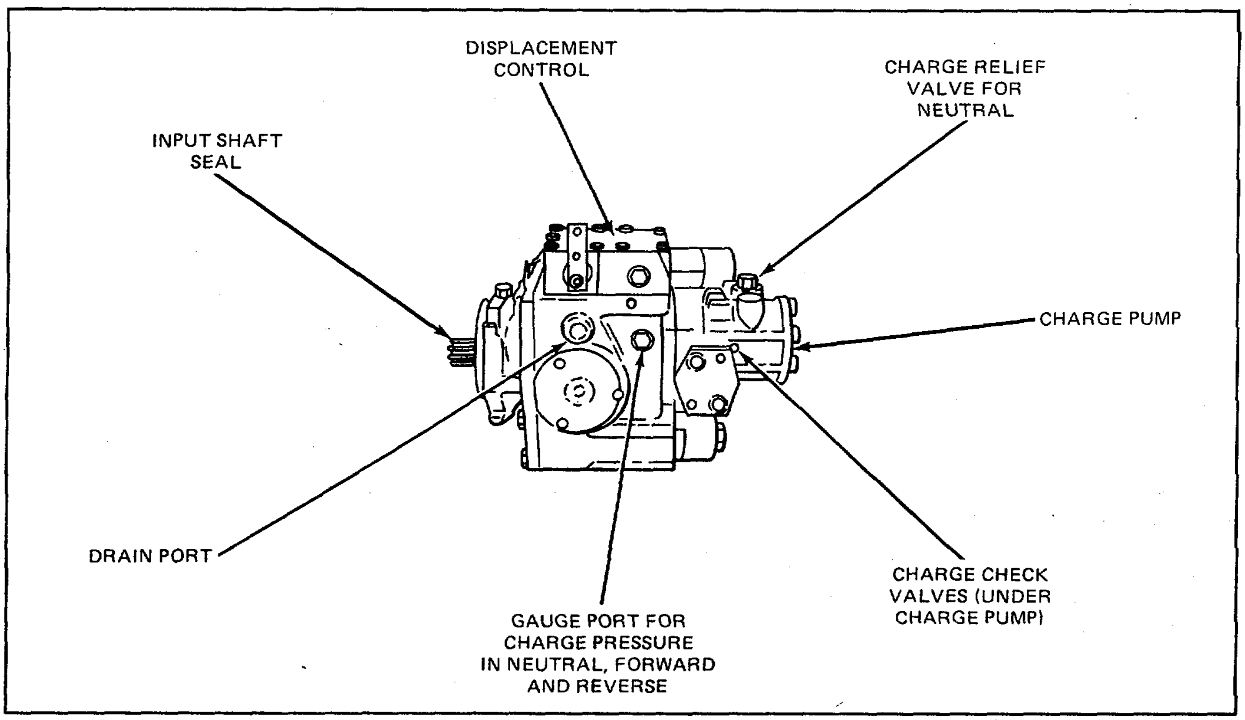


Figure 1.

Minor Repairs

Special Tools (refer to Fig. 2).

The following tools are required but not normally carried:

1. Truarc #7 Retaining Ring Pliers
2. Drag Link Socket
3. Torque Wrench

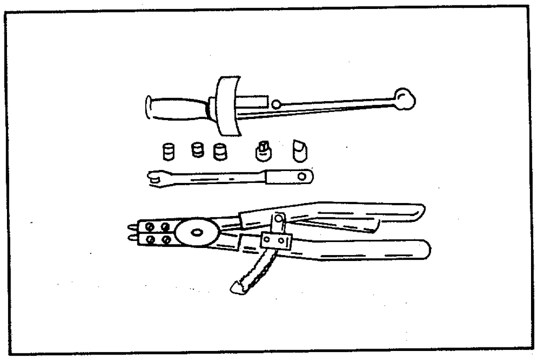


Figure 2.

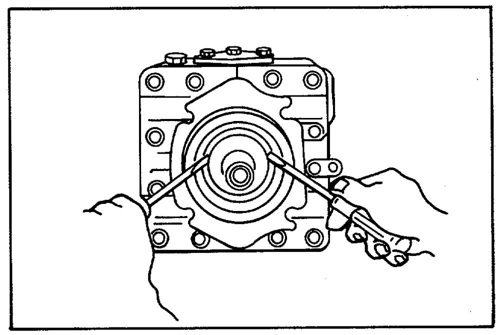


Figure 4.

It is recommended that all shaft seal parts be replaced. If parts are to be reused, they must be protected from being damaged by the shaft during removal.

Remove the large retaining ring located on the shaft end of the pump. Remove the side opposite the tangs from the groove first (refer to Fig. 3).

The aluminum housing is removed next. It is held in place by the friction of the O-ring on its O.D. Pry the housing toward the end of the shaft until the O-ring is free (refer to Fig. 4).

Remove the housing from the shaft. This part is actually an assembly that is being held together by the friction of an internal O-ring. It will normally remain assembled until physically separated (refer to Fig. 5).

The bronze sealing ring is also held in place by internal O-ring friction. Work this part free and carefully slide over the shaft (refer to Fig. 6).

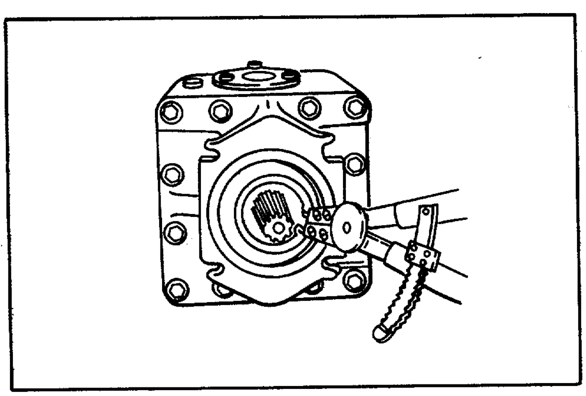


Figure 3.

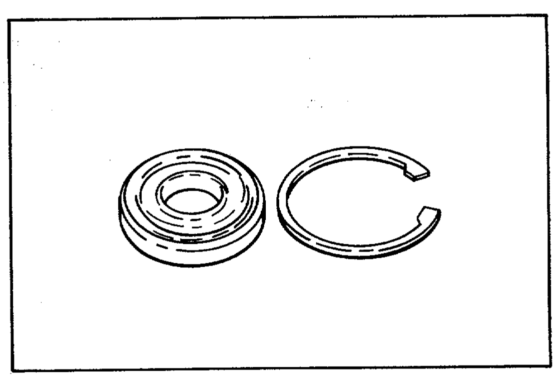


Figure 5.

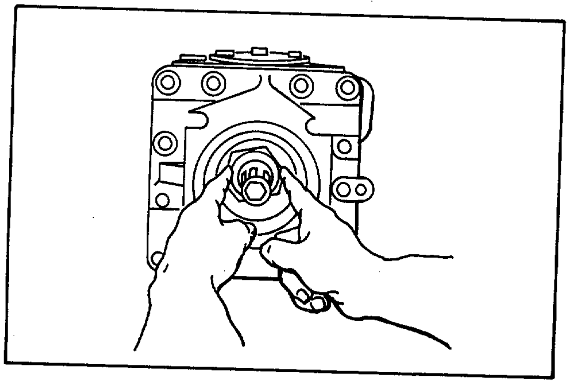


Figure 6.

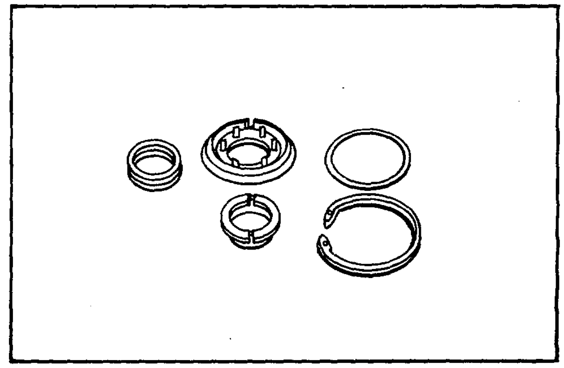


Figure 8.

All of the shaft seal parts, which are included in the shaft seal kit, have now been removed. Each part should be inspected separately if the seal is to be reused. It is recommended that this entire shaft seal be replaced (refer to Fig. 7).

Prior to assembly, place one O-ring in the I.D. of the bronze sealing ring and one O-ring in the I.D. of the aluminum housing. Place the six springs in the cavities in the housing. Care must be used to protect the parts from damage by the shaft during assembly (refer to Fig. 8).

Slide the sealing ring over the shaft and onto the shaft pilot diameter with the O-ring facing the pump. Work the ring into place using hand force only (refer to Fig. 9).

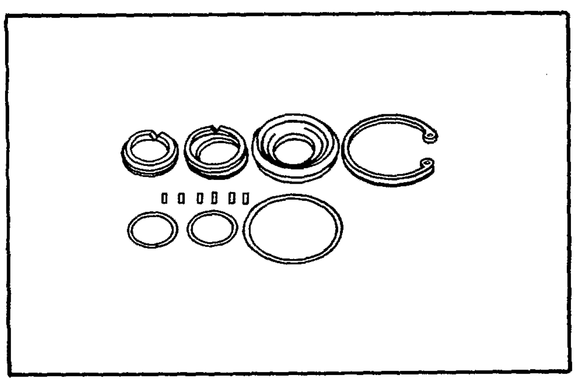


Figure 7.

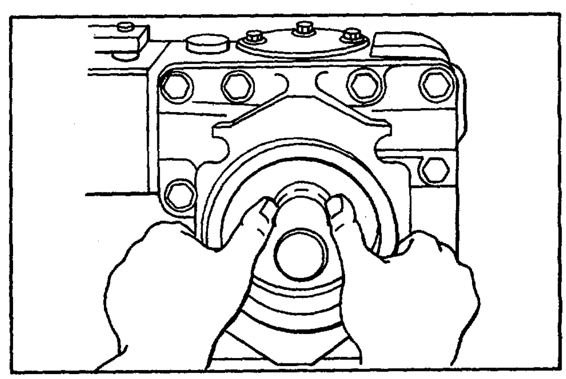


Figure 9.

Insert the stationary seal pilot into the aluminum housing, locating the notch in the stationary seal over the pin in the housing (refer to Fig. 10).

Install the O-ring on the O.D. of the housing, then slide it into place against the bronze sealing ring. Since this is a spring-loaded assembly, it may be necessary to push against the aluminum housing to expose the retaining ring groove (refer to Fig. 10).

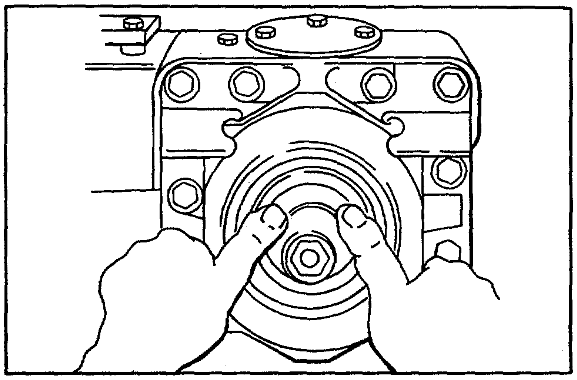


Figure 10.

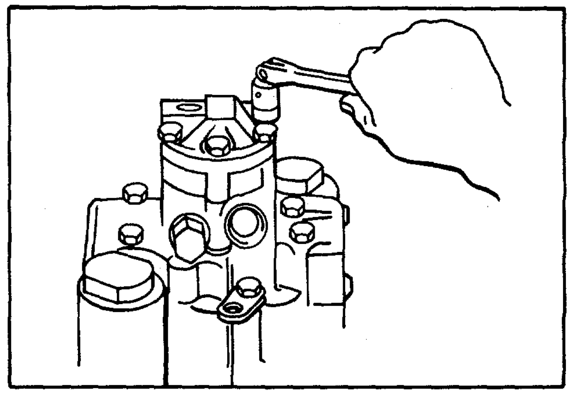


Figure 12.

Install the retaining ring with the beveled side out, putting the side opposite the tangs into the groove first. Be certain that the retaining ring has snapped into its groove completely (refer to Fig. 11).
To remove the charge pump, loosen the four capscrews that form a rectangular pattern on the rear of the charge pump.

Do not remove the screws at the top and bottom as these hold the segments of the pump together (refer to Fig. 12).

CAUTION

Protect exposed surfaces and ports to prevent damage and parts falling into main pump.

Before removing the charge pump, mark its housing and the main pump end cap to insure proper orientation when reassembling (refer to Fig. 12).

The charge pump lifts straight off the main pump. There is a spacer in the idler shaft bore that can slip out as the pump is removed; be certain to control this spacer so it cannot fall into the main pump (refer to Fig. 13).

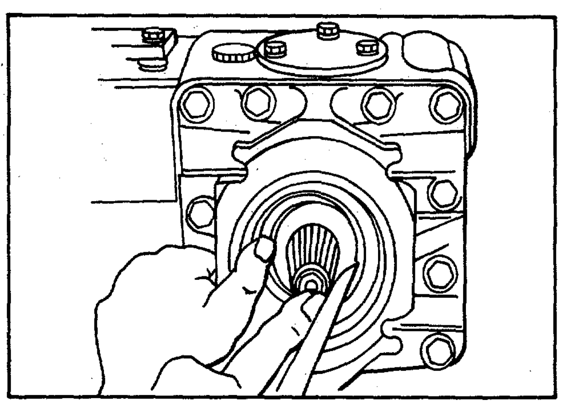


Figure 11.

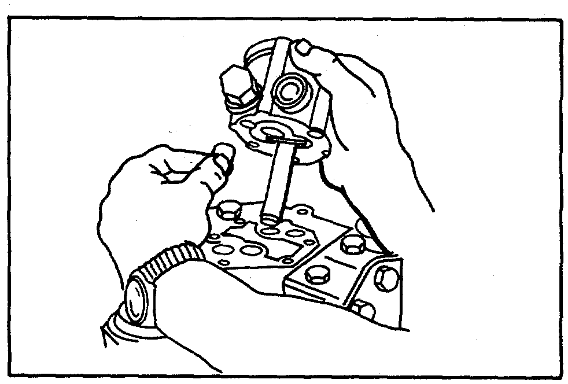


Figure 13.

There is a gasket between the charge pump and end cap that should be replaced (refer to Fig. 14).

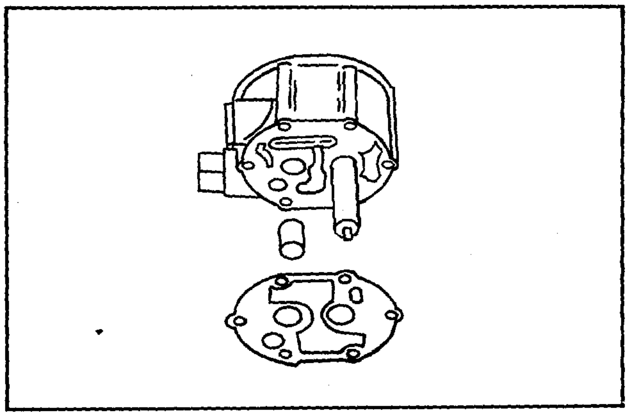


Figure 14.

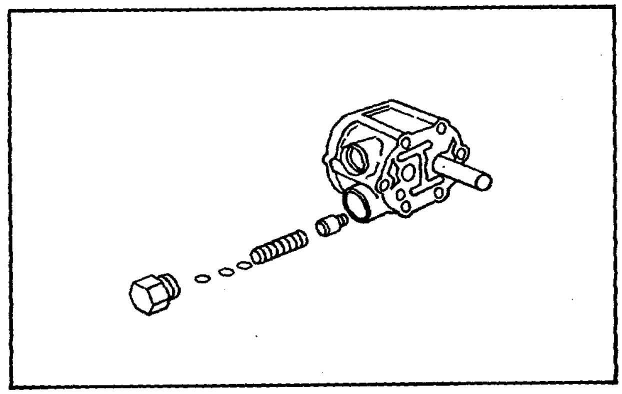


Figure 15.

The charge relief valve can be inspected by removing the hex plug, spring, and poppet. Remove the shims from the counterbore of the hex plug. Do not alter these shims unless new parts are used, in which case the valve must be reshimmed to the proper setting. (refer to Fig. 15).

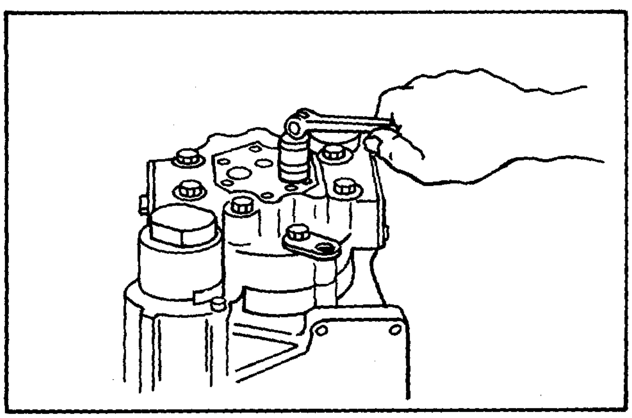


Figure 16.

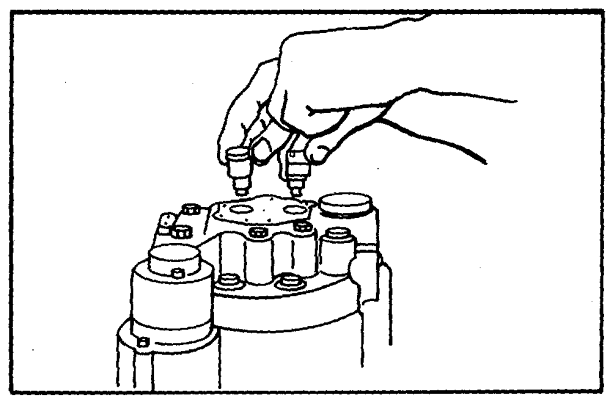


Figure 17.

The removal of the charge check valves requires the use of a drag-link socket (refer to Fig. 16).

These check valves are cartridges and are interchangeable with each other. It is suggested that these check valves be replaced in pairs (refer to Fig. 17).

Use caution when installing these valves to prevent damage to the O-ring on the cartridge as it is inserted past the threads (refer to Fig. 18).

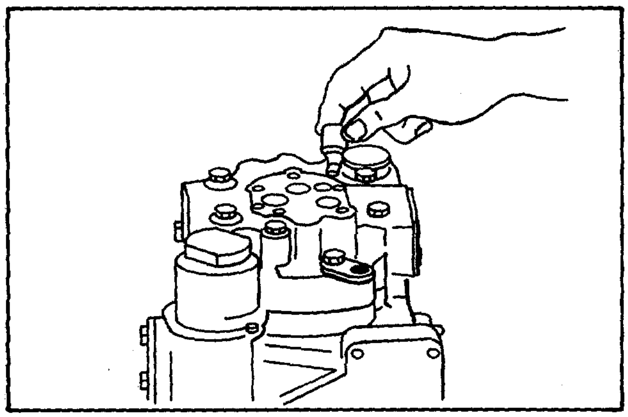


Figure 18.

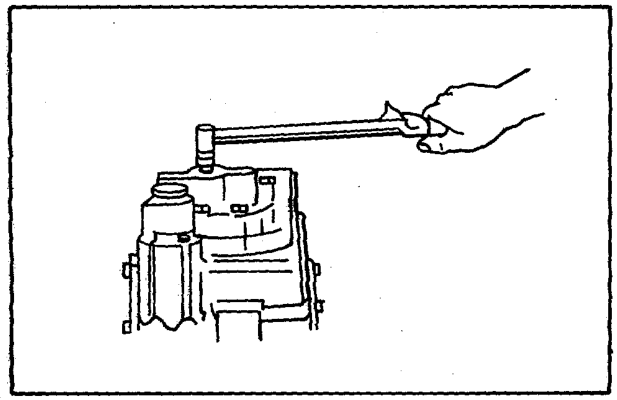


Figure 19.

After assembly be certain these valves are below the surface of the end cap (refer to Fig. 19). Torque values are specified at the end of this manual.

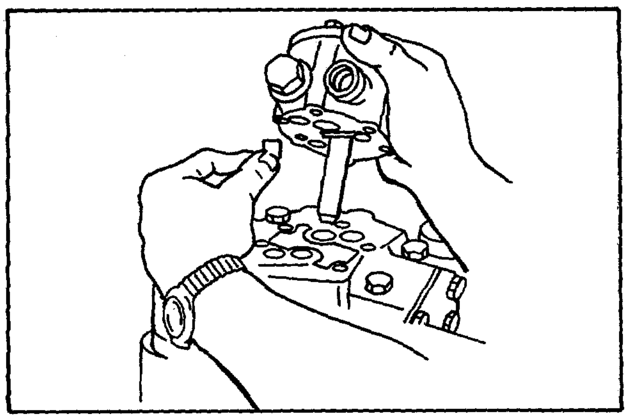


Figure 20.

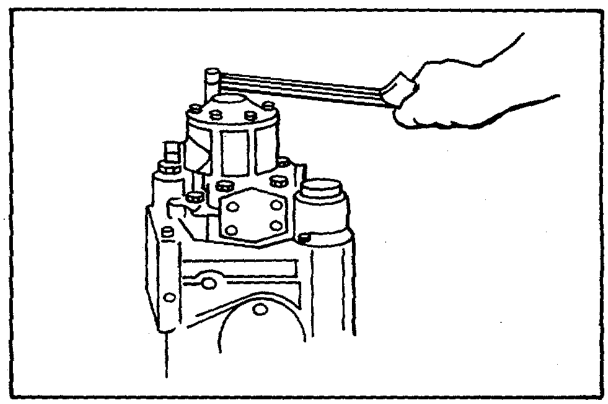


Figure 21

When replacing the charge pump, align the gasket so that the small relief valve port is open and not blocked by the gasket. Rotate the charge pump shaft so it aligns approximately with the slot in the end of the pump drive shaft. Hold the idler spacer in place and install the charge pump onto the end cap. Rotate the charge pump until the tang and slot engage and the pump is solidly on the end cap (refer to Fig. 20).

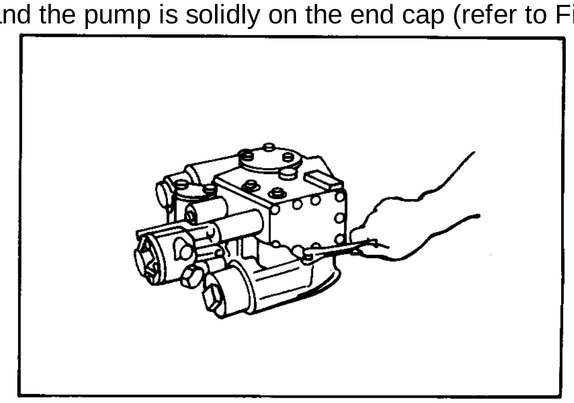


Figure 22.

Install the four hex capscrews and tighten (refer to Fig. 21).

Remove the hex capscrews and swing the control away from the pump housing. This area is sealed with both O-rings and a gasket (refer to Fig. 22).

Caution must be exercised after the control valve is swung away from the pump housing since this opens a large cavity into the housing. Also during removal and installation of the control link pin, parts can be dropped into the main housing, requiring total disassembly of the unit (refer to Fig. 23).

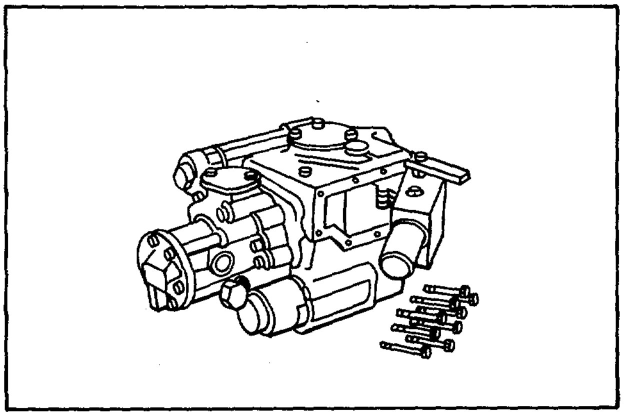


Figure 23.

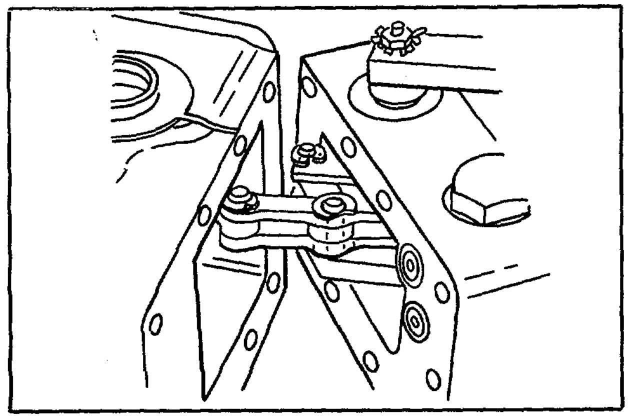


Figure 24.

Swing the control away from the housing as far as it will go to expose the cotter pin (refer to Fig. 24).

Remove the cotter pin, washer, and connecting pin. It is suggested that a piece of wire be inserted through the eye of the cotter pin so the pin can easily be retrieved if it falls into the pump (refer to Fig. 25).

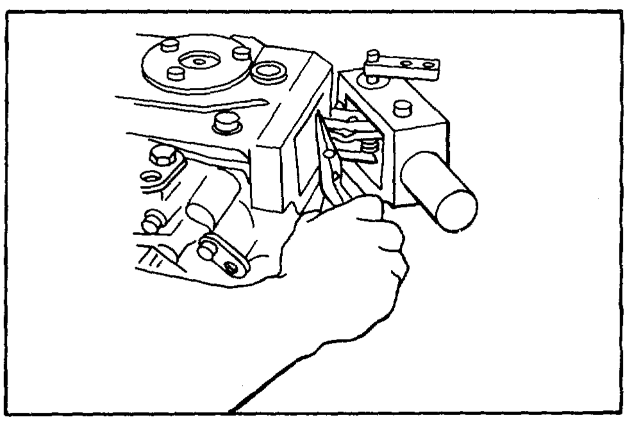


Figure 25.

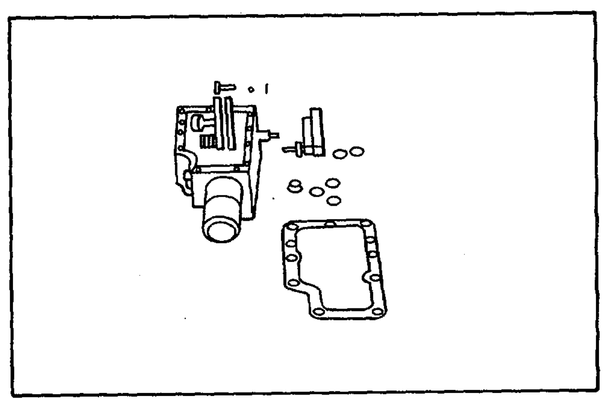


Figure 26.

In preparation for reinstalling the control, place a new gasket on the housing, and place the orifice plate and O-rings in the control (refer to Fig. 26).

Install the connecting pin through the control linkage and the feedback link on the swashplate with the headed side toward the center of the pump. Use caution not to drop parts into the pump housing (refer to Fig. 27).

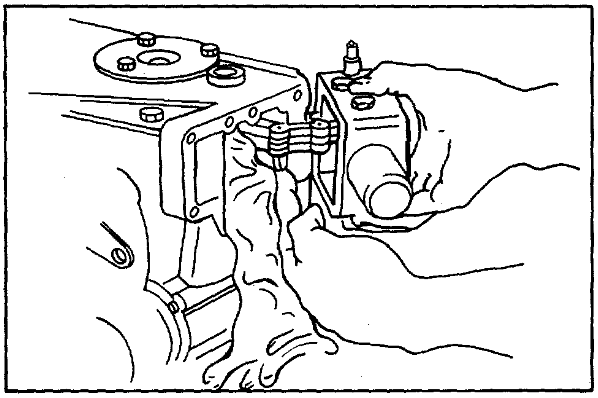


Figure 27.

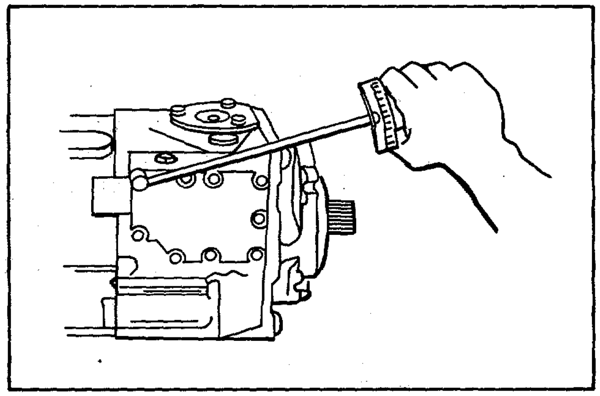


Figure 28

Swing the control into place against the housing, being certain the orifice and O-rings are in place, then install capscrews (refer to Fig. 28).

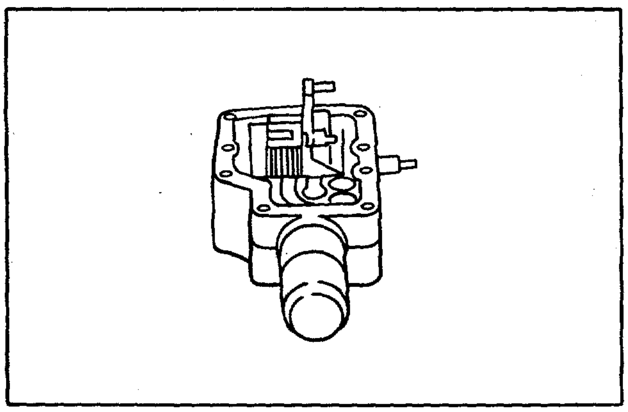


Figure 29.

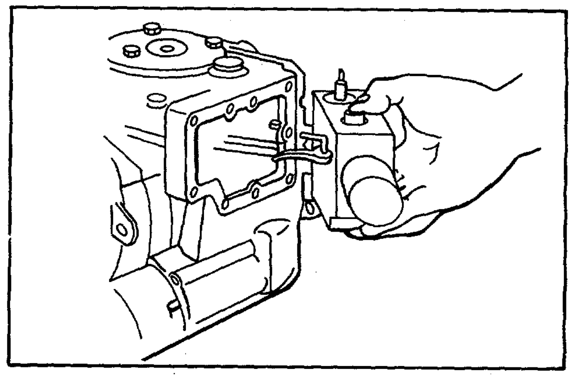


Figure 30.

The displacement control link has been redesigned. Some units will use this new one-piece welded design (refer to Fig. 29).

Engage the pin on the control link in the mating hole in the small link attached to the swashplate (refer to Fig. 30).

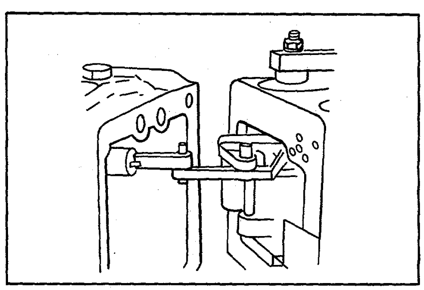


Figure 31.

Slide the pin all the way into the swashplate link and then swing the control into place against the housing as previously described (refer to Fig. 31).

Major Repair

Special Tools (refer to Fig. 1).

The following tools are required but not normally carried:

1. Waldes Truarc #7 Retaining Ring Pliers.
2. Drag Link Socket
3. 12-Point, 3/16 Socket
4. Torque Wrench
5. Tapered Bearing Puller
   Ref. Snap on Part Numbers
   Puller Bar CG350
   20-23 Series: Separator CJ950
   24-28 Series: Separator CJ951

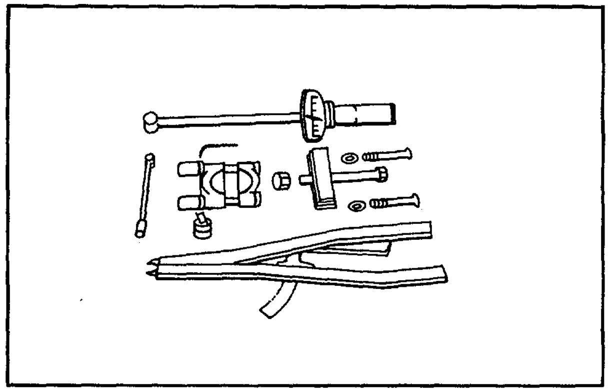


Figure 1.

Remove the shaft seal (refer to Fig. 2) as outlined under Minor Repair Procedures. The shaft seal must be removed before the end capscrews are loosened to prevent the seal being damaged.

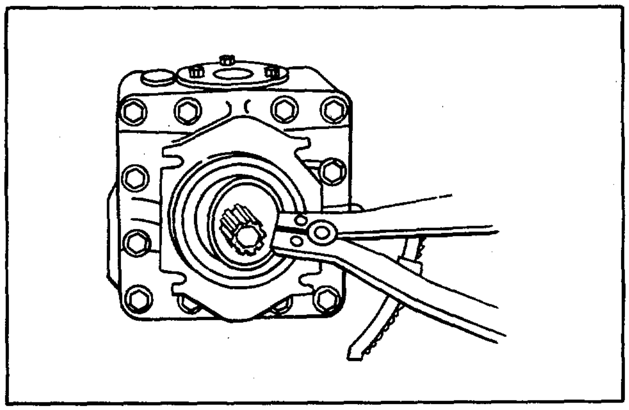


Figure 2.

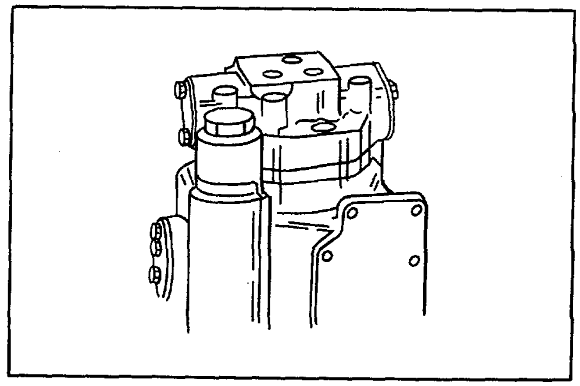


Figure 3.

CAUTION

The end capscrews should not be loosened until the shaft seal has been removed.

Remove charge pump and control valve as outlined under Minor Repair Procedures.

Remove all but two of the hex capscrews holding the end cap to the housing (refer to Fig. 3).

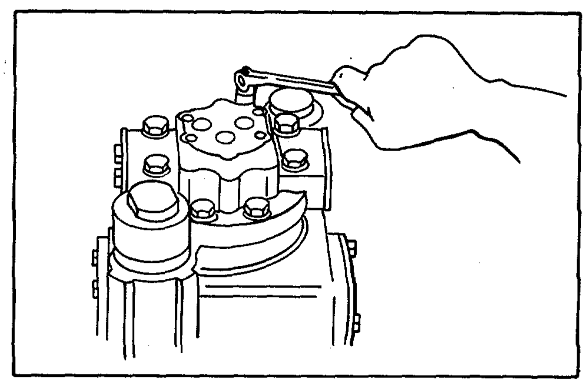


Figure 4.

There is an internal spring loading on the end cap and as the last two screws are loosened, it should begin to separate from the housing. Loosen these screws alternately until the end cap has fully separated from the housing, then remove the screws entirely (refer to Fig. 4).

The end cap can now be lifted off the pump; however, be certain that the valve plate does not fall and become damaged. If the valve plate tends to lift off with the end cap, hold it in place on the end cap and remove both parts together. If the valve plate remains on the bearing plate, remove it at this time (refer to Fig. 5).

CAUTION

All surfaces exposed are critical and caution must be used to avoid damage.

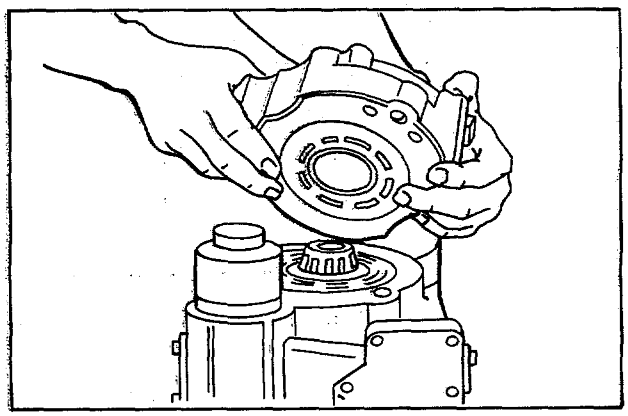


Figure 5.

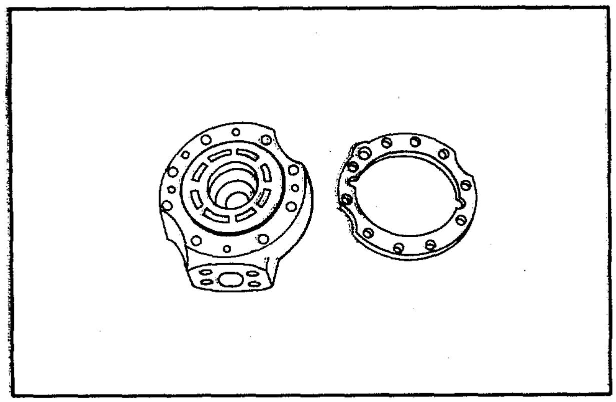


Figure 6.

Note that the end cap is sealed to the housing with both a gasket and an O-ring (refer to Fig. 6).

The end cap is actually an assembly consisting of a tapered bearing race (which is a slip fit-in the end cap) and the valve plate locating pin. These parts should be removed from the end cap. There may or may not be a shim located under the bearing race which should be removed (refer to Fig. 7).

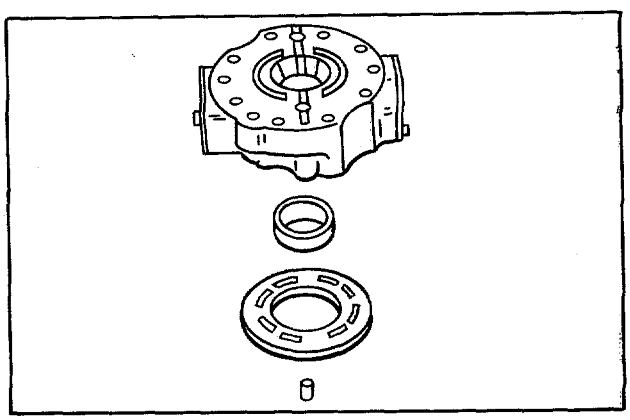


Figure 7.

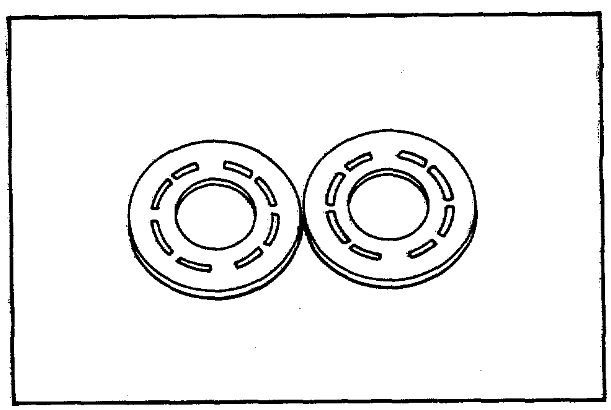


Figure 8.

The pump valve plate has two tapered slots, one at the top and one at the bottom of the plate. These slots are on opposite ports for different shaft rotations (refer to Fig. 8).

The valve plate on the left in the picture is for left-hand (counterclockwise) rotation. The valve plate on the right is for right-hand (clockwise) rotation (refer to Fig. 8).

Remove the bronze bearing plate and the pilot ring from the cylinder block. If the pilot ring remains with the bearing plate, remove it at this time (refer to Fig. 9).

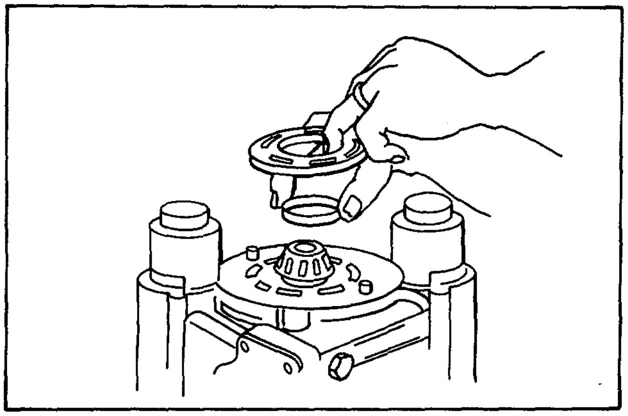


Figure 9.

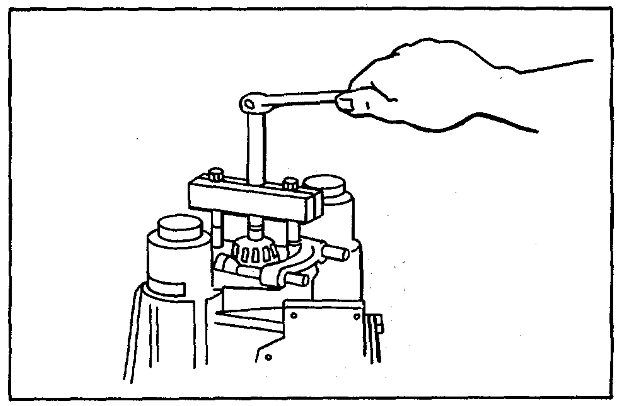


Figure 10.

The tapered bearing must now be removed from the shaft. A bearing puller should be used that will pull against the inner race of the bearing. A spacer is required to protect the slot in the end of the pump shaft from the puller screw. Protect the face of the cylinder block during this operation (refer to Fig. 10).

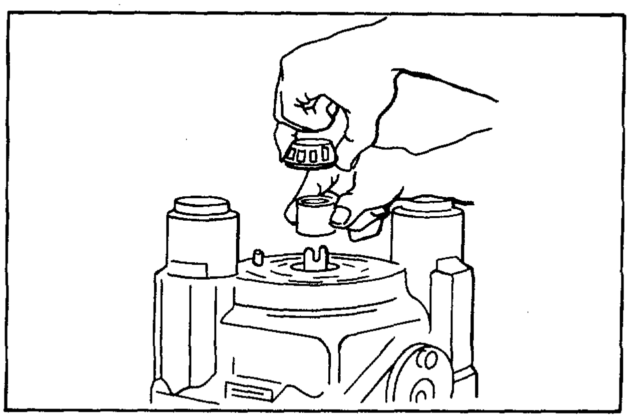


Figure 11.

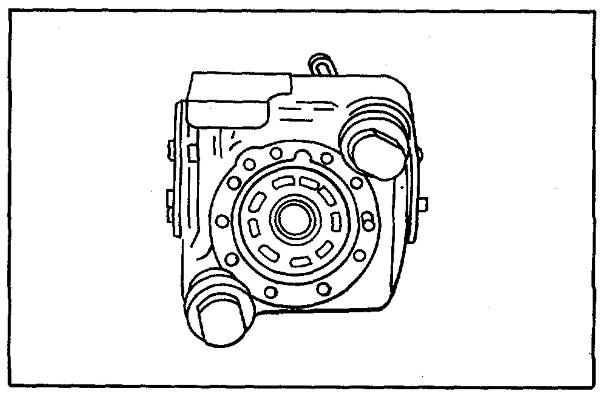


Figure 12.

After removal of the bearing, slip the spacer out of the bore in the cylinder block (refer to Fig. 11).

Place the pump horizontally in preparation for removal of the cylinder block assembly (refer to Fig. 12).

Slide the cylinder block assembly off the shaft while holding the external end of the shaft (refer to Fig. 13).

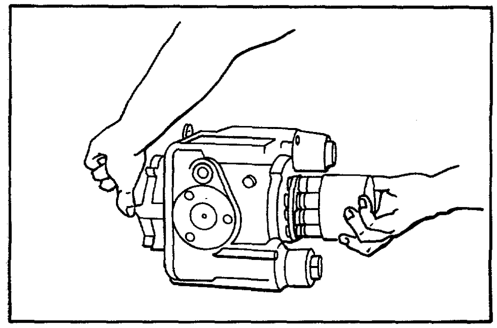


Figure 13.

If the cylinder block assembly does not remain together during removal, it can be easily reassembled at a later time (refer to Fig. 14).

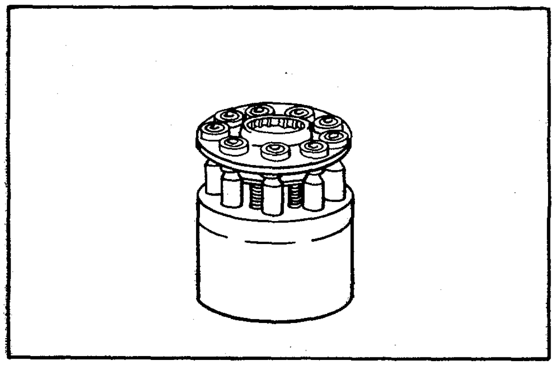


Figure 14.

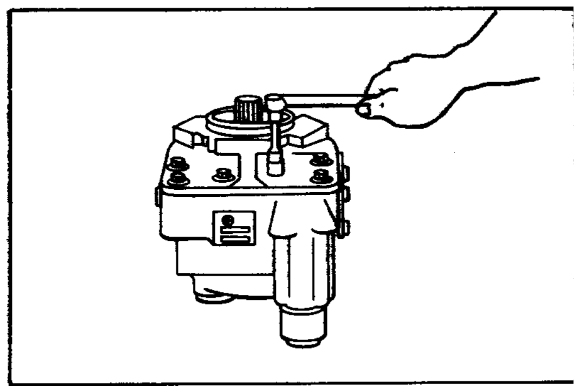


Figure 15.

Set the pump on the servo housings and remove the front cover screws (refer to Fig. 15).

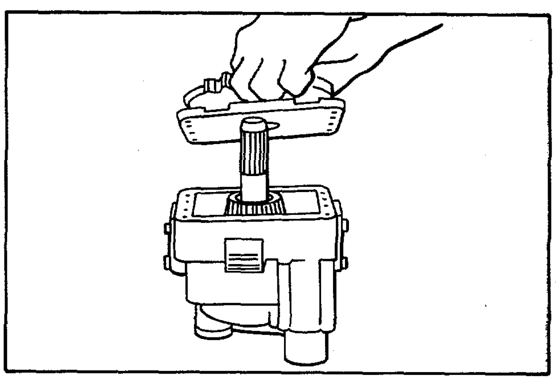


Figure 16.

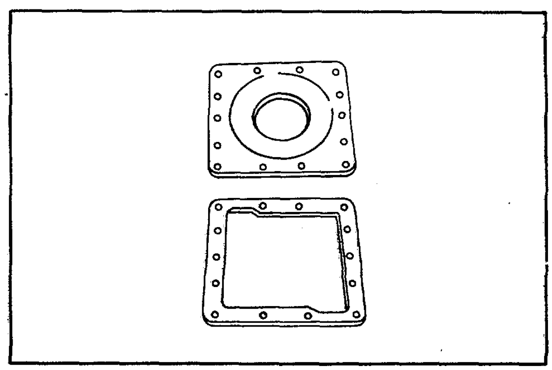


Figure 17.

Lift off the front cover and gasket (refer to Fig. 16).

The race for the tapered shaft bearing is a press fit in the front cover (refer to Fig. 17).

Lift the shaft and bearing out of the center hole of the swashplate (refer to Fig. 18).

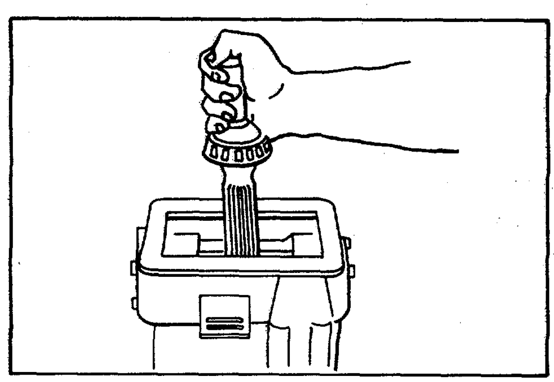


Figure 18.

Remove thrust plate from its counter bore in the face of the swashplate. Reach through the center hole in swashplate and push against exposed edge of thrust plate. Do not allow part to fall and become damaged (refer to Fig. 19).

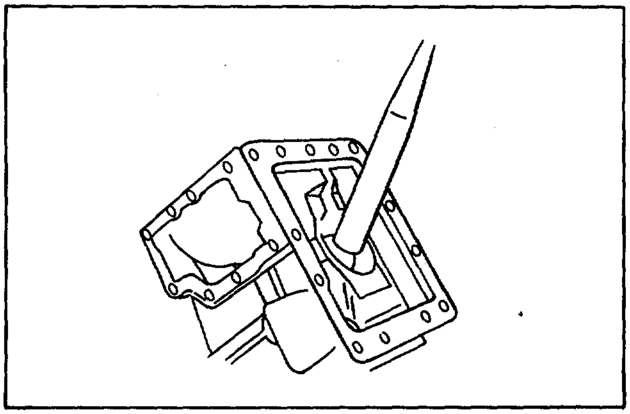


Figure 19.

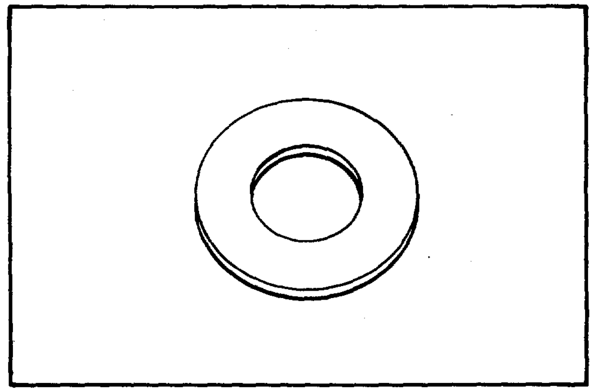


Figure 20.

Thrust plate (refer to Fig. 20).

The tapered bearing can be pressed off the shaft if required. Be careful not to damage the seal diameter of the shaft while removing the bearing (refer to Fig. 21).

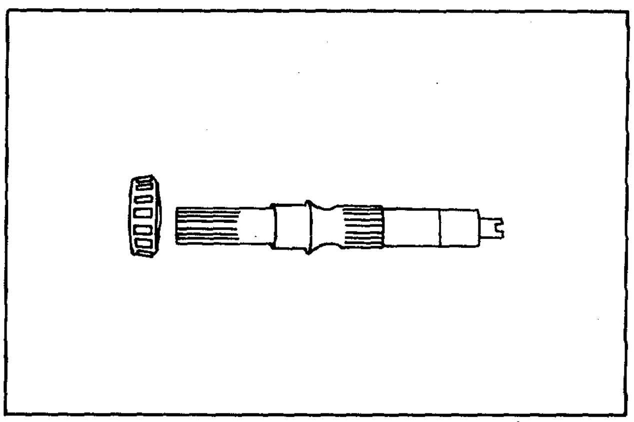


Figure 21.

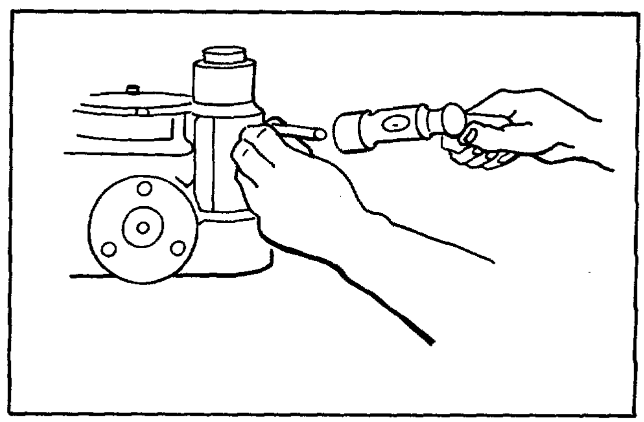


Figure 22.

From this point on it is necessary to mark all parts so that neutral (zero swashplate angle) will be retained when the parts are reassembled. The swashplate is held in neutral by springs inside the servo housings. These springs are adjusted by turning the servo housings (refer to Fig. 22).

First, mark the servo housing for location to the pump housing. This set of marks should line up to show the rotational position of the servo housing to the pump housing (refer to Fig. 23).

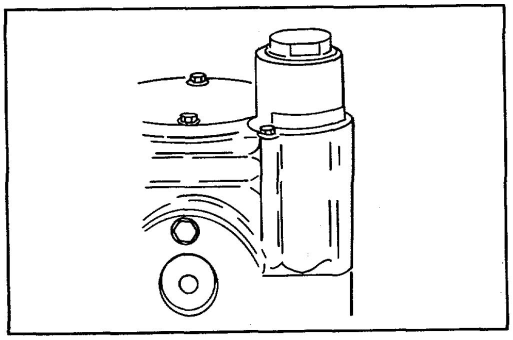


Figure 23.

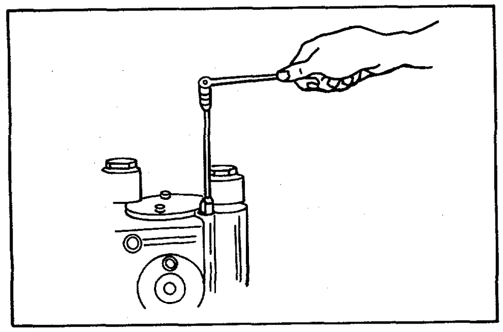


Figure 24.

Remove the locking retainers using a 12-point, 3/16 socket for the capscrews (refer to Fig. 24).

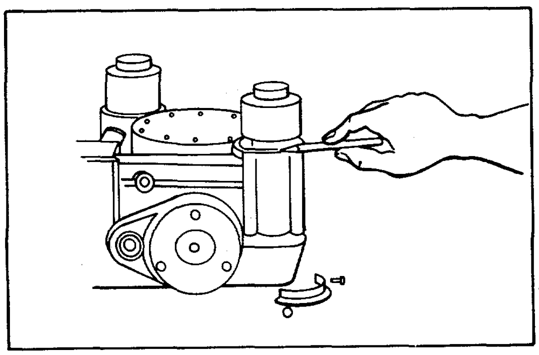


Figure 25.

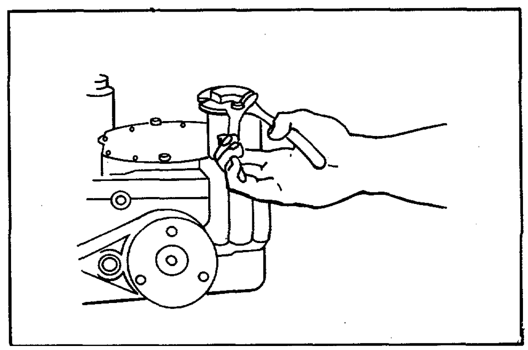


Figure 26.

After removing the retainers, scribe a line to mark the height of the servo housing in relation to the pump housing (refer to Fig. 25).

Unscrew the servo housings using channel-lock pliers to grip the flats on top of the housings (refer to Fig. 26 and 27).

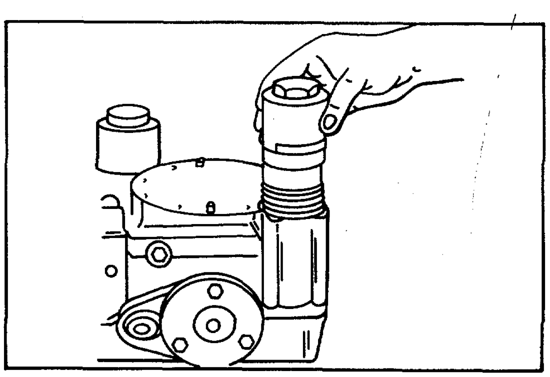


Figure 27.

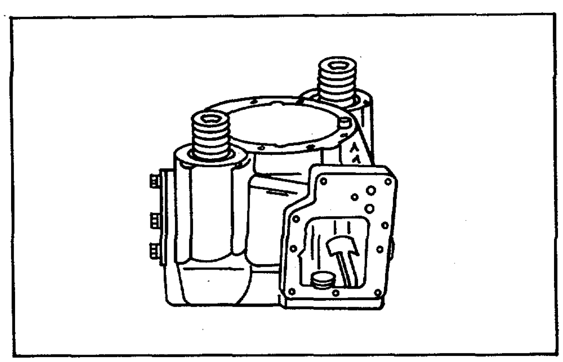


Figure 28.

At this time the servo springs should be removed if replacement is necessary, as the pump housing will provide a means of leverage when breaking the screws loose (refer to Fig. 28).

Do not reuse the screw holding the spring to the servo piston as it has a nylon-locking insert that is not effective when reused. These springs should not be removed unless necessary (refer to Fig. 29).

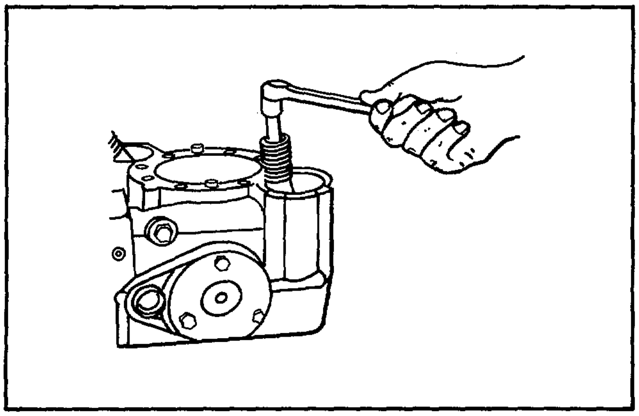


Figure 29.

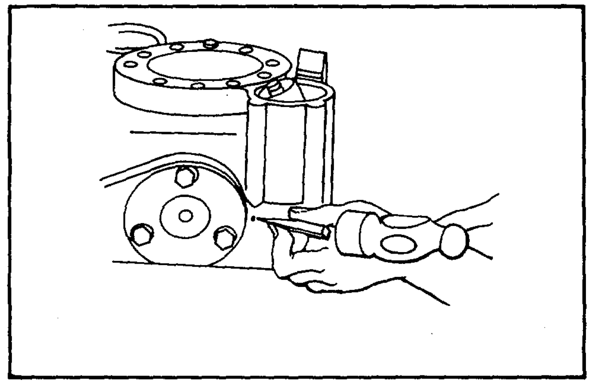


Figure 30.

The trunnions should be marked to insure reassembly to the correct side of the housing (refer to Fig. 30).

Remove the hex head screws from each trunnion (refer to Fig. 31).

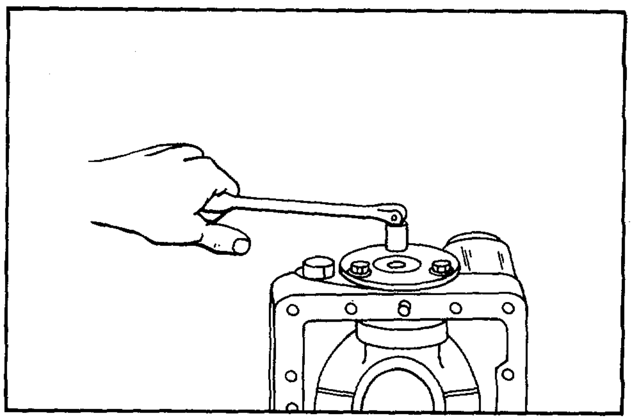


Figure 31.

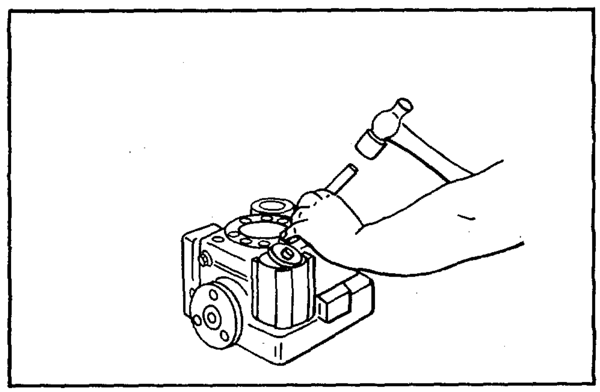


Figure 32.

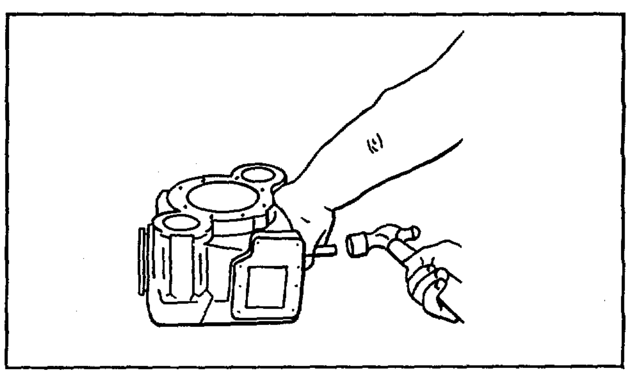


Figure 33.

Friction caused by the O-ring on the trunnion can make it necessary to drive the trunnion assembly out of the housing (refer to Fig. 32 and 33).

Be certain to keep the plastic shims with the proper trunnion to insure satisfactory bearing adjustment after reassembly (refer to Fig. 34).

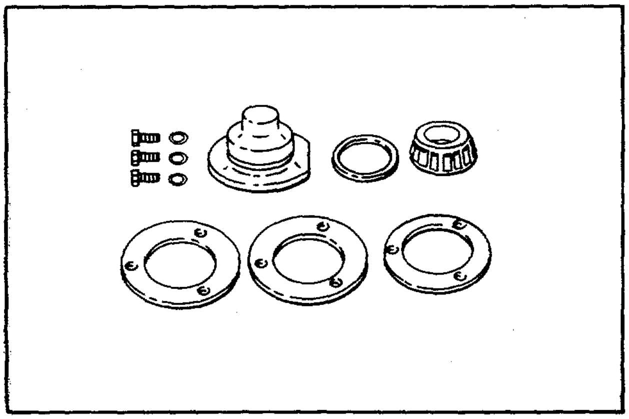


Figure 34.

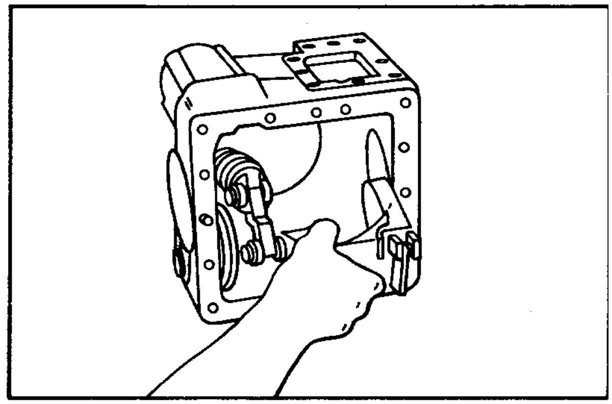


Figure 35.

After both trunnion assemblies have been removed, the swashplate assembly can be removed from the pump housing (refer to Fig. 35).

Layout of parts showing swashplate, servo pistons and springs, feedback link and trunnions (refer to Fig. 36).

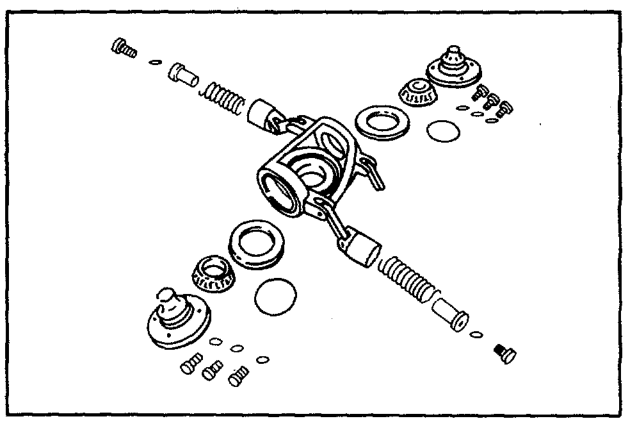


Figure 36.

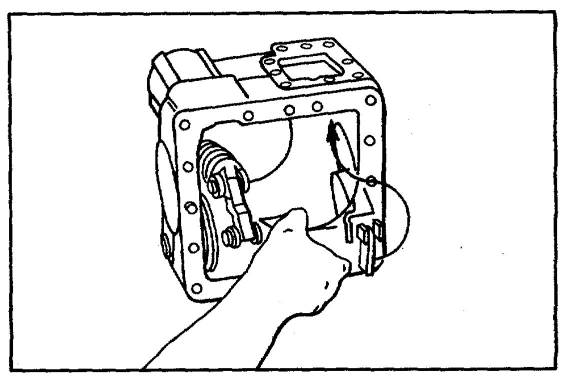


Figure 37.

When installing the swashplate assembly into the housing, the feedback link must be laid back along the top of the swashplate so it can be reached through the opening for the control valve (refer to Fig. 37).

After installing swashplate be certain feedback link is accessible (refer to Fig. 38).

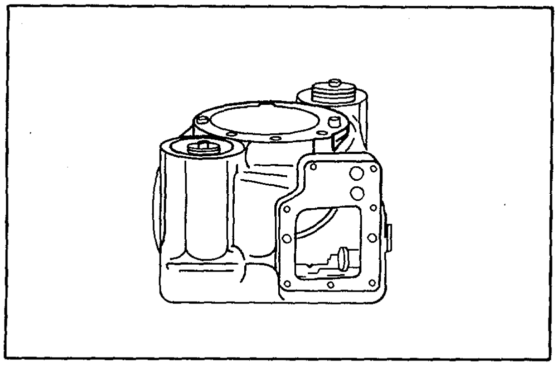


Figure 38.

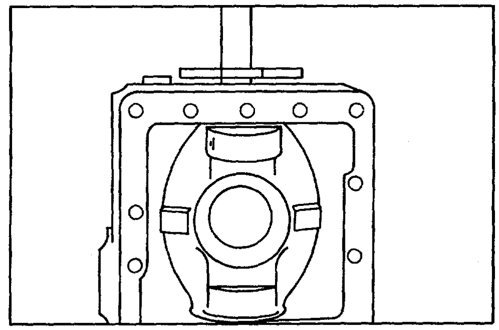


Figure 39.

Install the trunnions, checking for proper orientation with the housing and tighten the capscrews. The swashplate should have no sideplay yet rotate freely. If necessary, alter the plastic shims to obtain the proper adjustment (refer to Fig. 39).

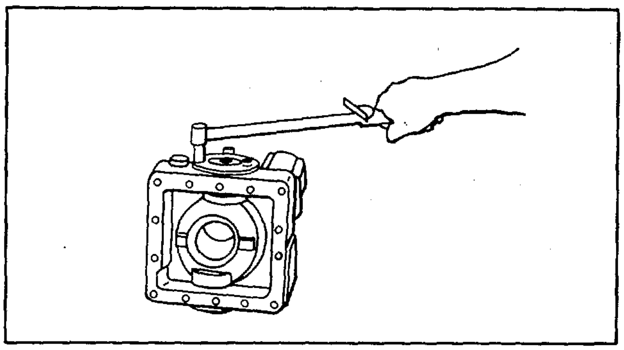


Figure 40.

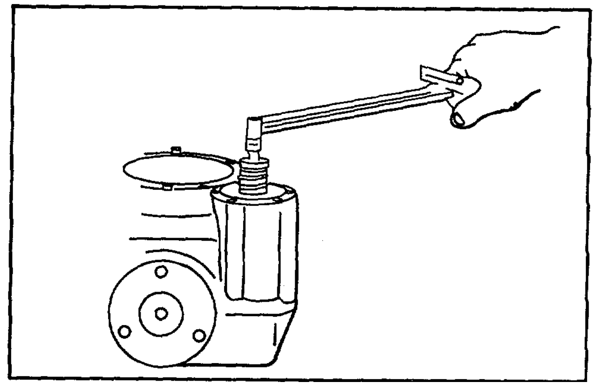


Figure 41.

Install and tighten the trunnion capscrews (refer to Fig. 40).

Install the servo springs, if these parts were removed, using new screws (refer to Fig. 41).

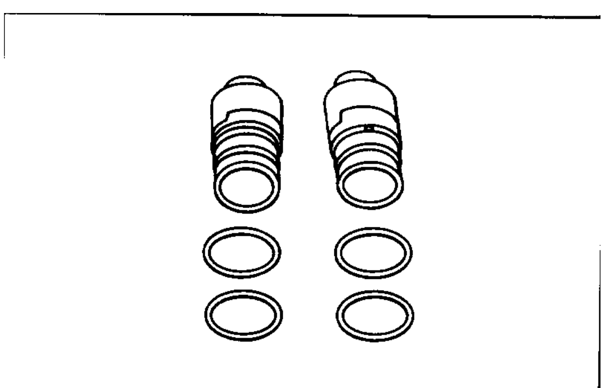


Figure 42.

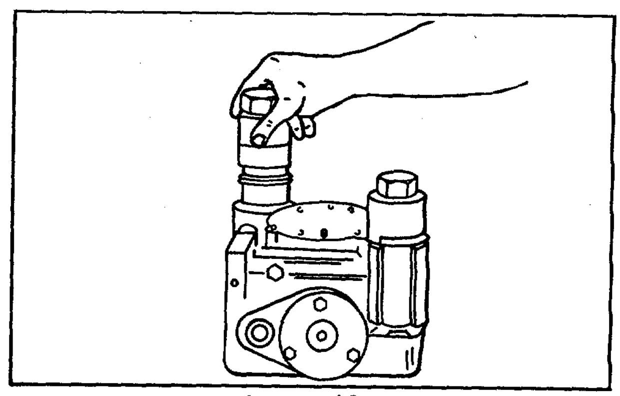


Figure 43.

The servo housings should be installed next (refer to Fig. 42).

Slide the housing over the servo piston and thread it into the pump housing (refer to Fig. 43).

Adjust the housing to the height and rotational position as determined by the markings made during disassembly (refer to Fig. 44).

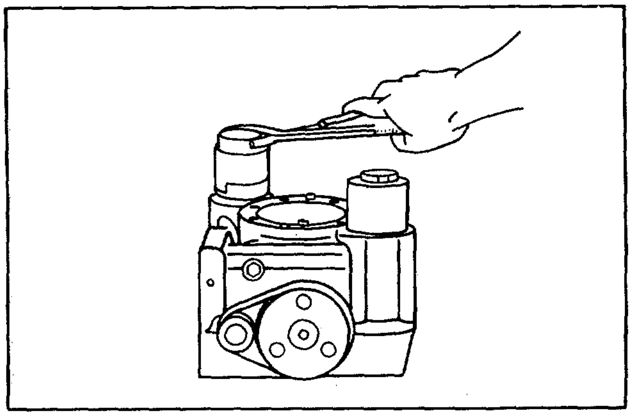


Figure 44.

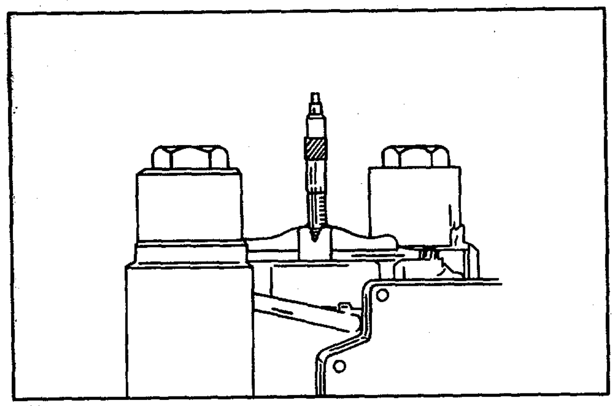


Figure 45.

The neutral (zero angle) position of the swashplate must now be checked using a depth micrometer (refer to Fig. 45).

The thrust plate must be installed on the swashplate for this measurement. Measure the distance from the end cap mounting face of the pump housing to the face of the thrust plate 90° to the trunnions, at the outer edge of the thrust plate. Take the same measurement at a point 180° (opposite edge of the thrust plate) from the first. These measurements must not vary more than 0.001 inch from each other (refer to Fig. 45).

If adjustment is required follow these steps (refer to Fig. 46).

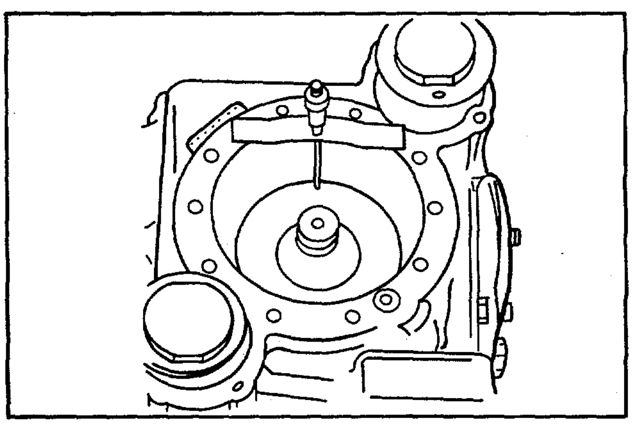


Figure 46.

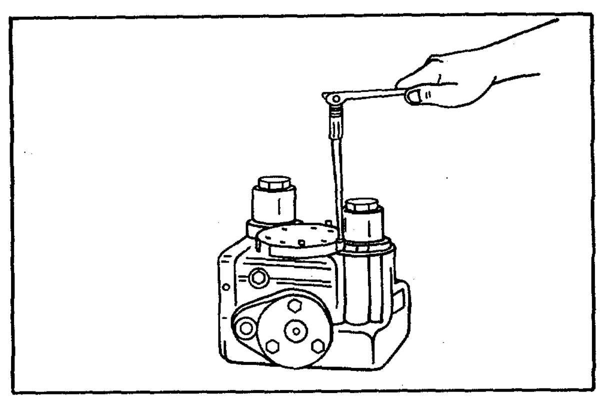


Figure 47.

1. Back out both servo housings until the spring load is released on the swashplate (check by rocking swashplate).
2. Thread in each housing until spring load just starts to be felt on the swashplate.
3. Check measurements as described previously.
4. Thread each housing farther in until the measurements are within 0.001 inch of each other.

After adjustment has been completed, the retainers can be installed and peened into the locking slot on the housing (refer to Fig. 47).

Remove the thrust plate and set the pump on the servo housings (refer to Fig. 48).

Insert the shaft and bearing assembly through the cast hole in the swashplate, allowing the bearing to rest on the cast leveled edge (refer to Fig. 48).

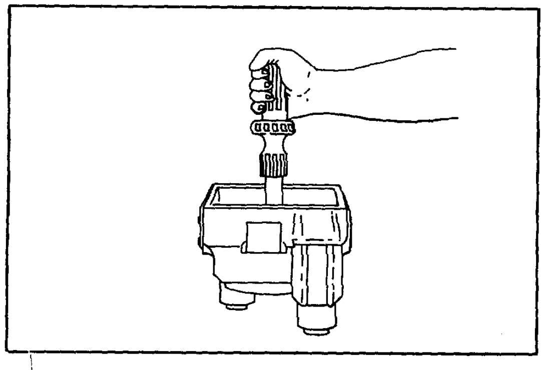


Figure 48.

If any of the following parts are replaced, the shaft end play must be checked:

Drive Shaft

Bearings

Housing

Front Cover

End Cap

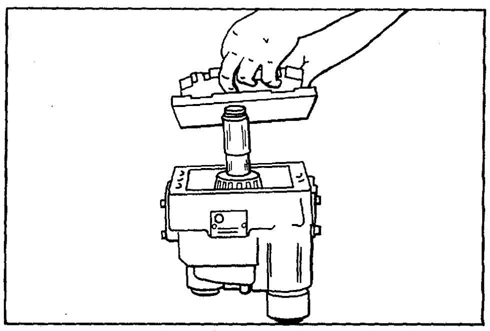


Figure 49.

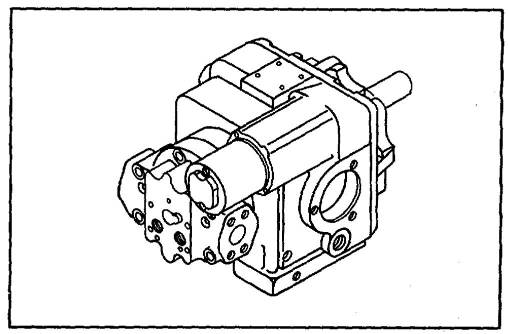


Figure 50.

To check the shaft end play, assemble the above parts plus the gaskets. The shaft end play should be from 0.006 inch to 0.016 inch. If adjustment is necessary, a shim can be placed under the bearing race in the end cap. Disassemble these parts and resume reassembly procedure (refer to Fig. 49 and 50).

Install the front cover and gasket, being certain that the locating pins are in place in the housing. These parts will go on only one way and have all the mounting holes align with the housing (refer to Fig. 51)

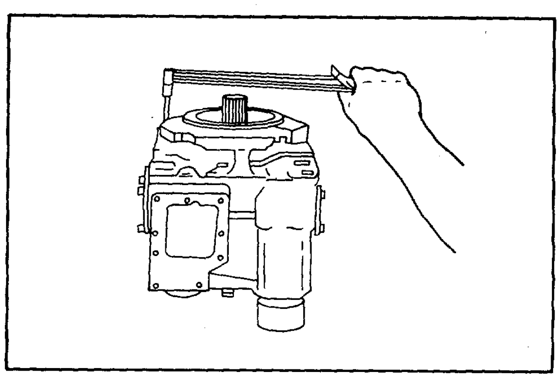


Figure 51.

Turn the unit on its side with the large control cavity on top and install the thrust plate. Lubricate the thrust plate with clean hydraulic oil prior to assembly (refer to Fig. 52).

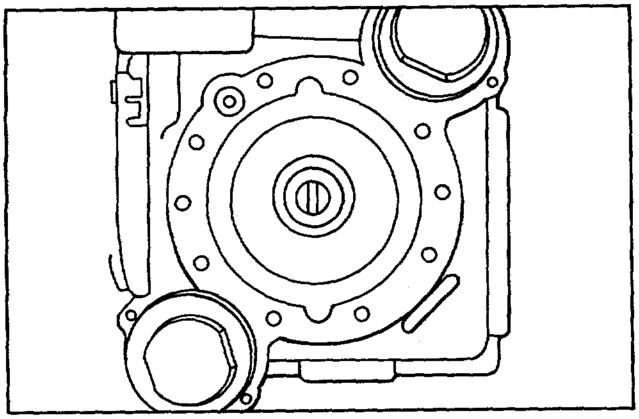


Figure 52.

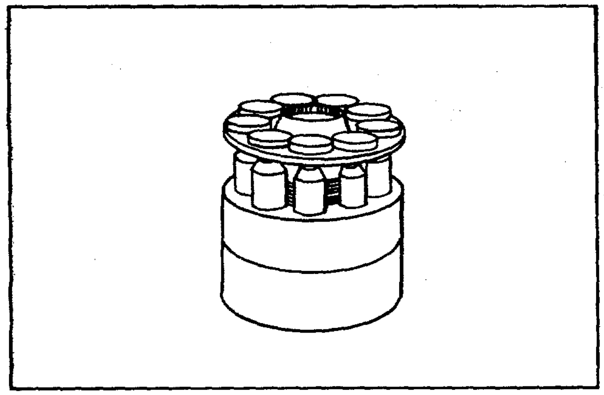


Figure 53.

The cylinder block assembly should be installed next. It is necessary to check the alignment of certain parts. There is no special relationship of pistons, bores, springs, etc. ; however, the alignment of the ball guide and cylinder block splines is critical. The undersized tooth in the spline of the cylinder block must line up with the missing tooth in the ball guide spline (refer to Fig. 53).

These in turn line up with a missing tooth on the shaft spline. The hole for the bearing plate locating pin in the cylinder block face is in line with the undersize tooth in the cylinder block and provides an assembly guide (refer to Fig. 54 and 55).

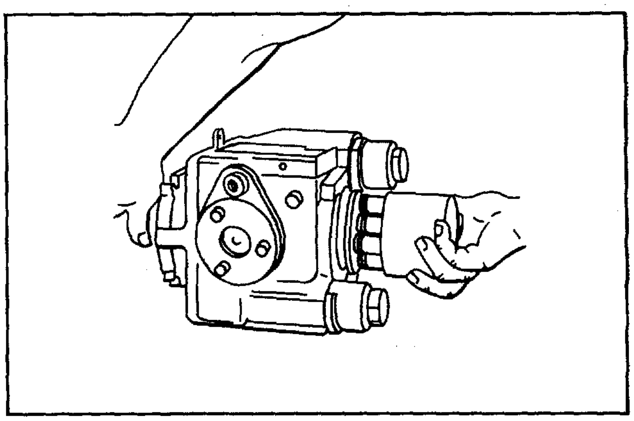


Figure 54.

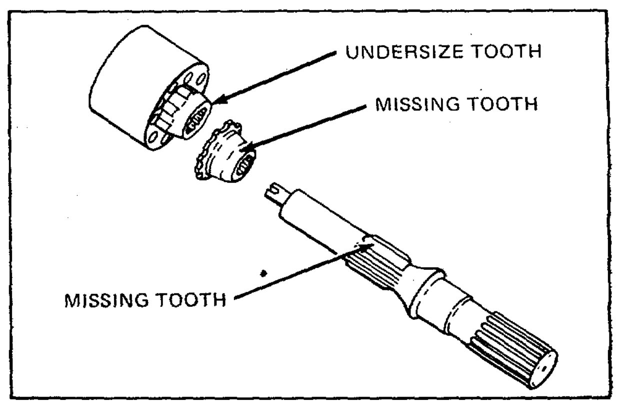


Figure 55.

Lubricate the thrust plate, slippers, pistons, and bores with clean hydraulic oil. Hold the shaft on the external end, align the missing tooth of the shaft and ball guide sighting through the control cavity and using the locating pin hole as a guide. Slide the cylinder block assembly onto the shaft and against the thrust plate.

When properly installed a spring load can be felt when pushing against the cylinder block (refer to Fig. 54, 55, and 56).

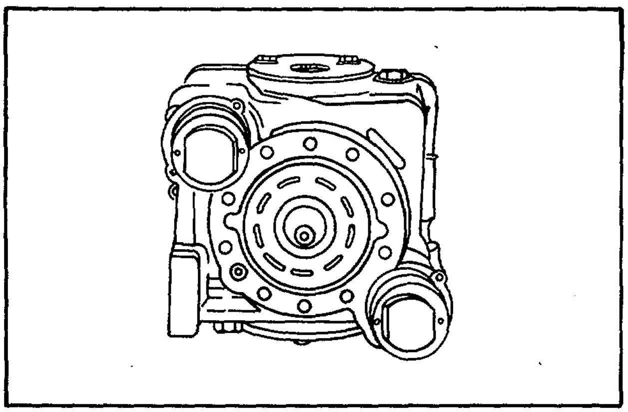


Figure 56.

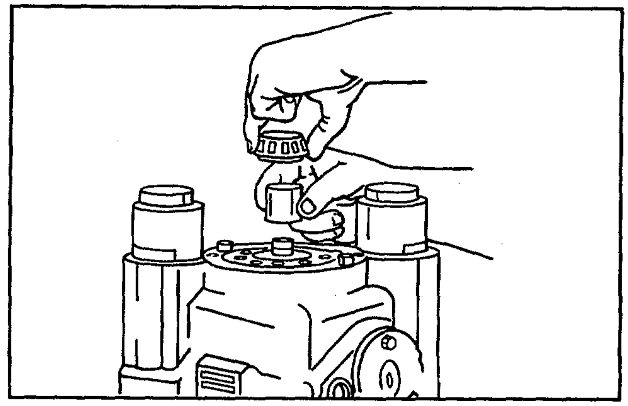


Figure 57.

Set the pump vertically and install the spacer into the center bore of the cylinder block (refer to Fig. 57).

The tapered bearing should be installed with an arbor type press for the most satisfactory results. This bearing cannot be driven onto the shaft due to the internal spring loading of the cylinder block and shaft. Press on the inner race of the bearing and use care not to damage roller cage (refer to Fig. 58).

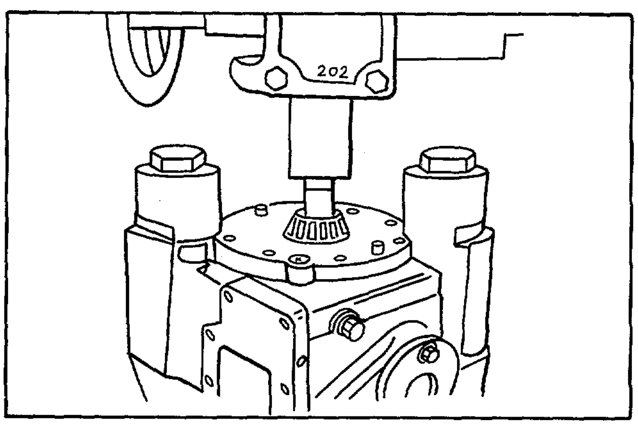


Figure 58.

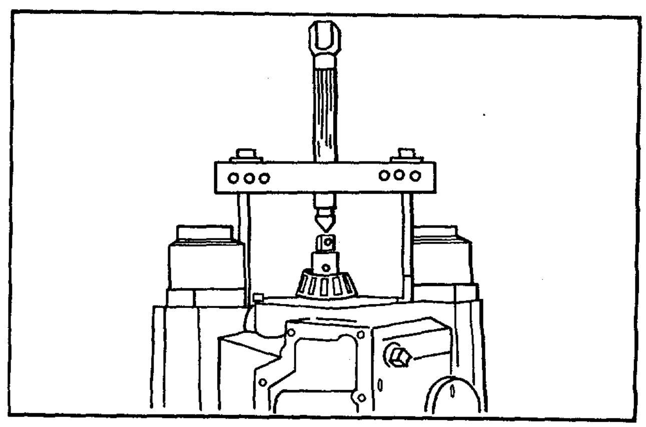


Figure 59

An alternate method of installing this bearing is to use the bearing puller bar and press the bearing onto the shaft with the center screw of the puller bar. A spacer must be used between the center screw and the bearing (refer to Fig. 59).

The bearing must be pressed on until it rests on the shoulder of the shaft to insure adequate bearing clearance (refer to Fig. 60).

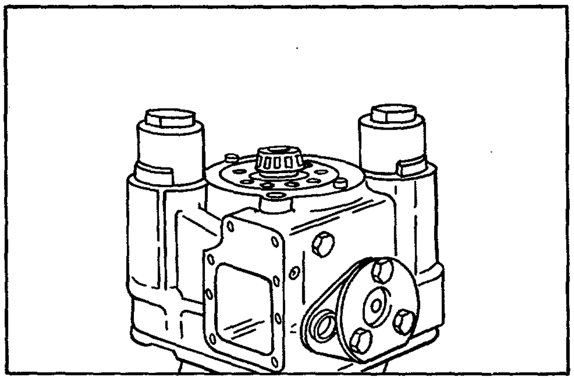


Figure 60.

Install the pilot ring in the bearing plate and the locating pin in the cylinder block. Install the bearing plate so that the milled slot locates over the pin and the pilot ring fits in the center bore of the cylinder block. After installation, lubricate the exposed surfaces with clean hydraulic oil (refer to Fig. 61).

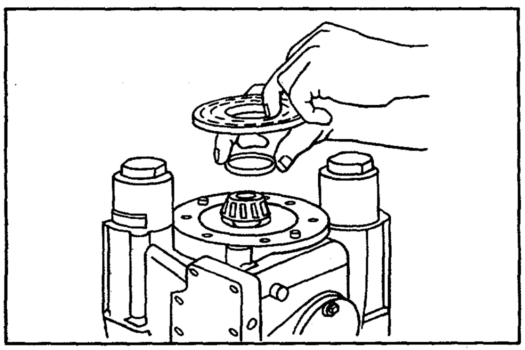


Figure 61.

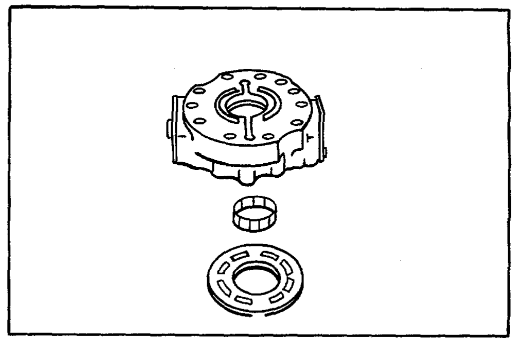


Figure 62.

Assemble the bearing race, shim (if required), and locating pin in the end cap. Check the valve plate to be certain it is a pump valve plate (has two tapered slots) and that it is for correct rotation (slots point away from direction of rotation) (refer to Fig. 62).

Lubricate the end cap face with clean hydraulic oil. Install the valve plate so that the slot locates over the pin and the center bore fits over the protruding bearing race. Place the end cap gasket on the housing, being certain the locating pins are in place, then install the O-ring in the counter bore in the housing (refer to Fig. 63).

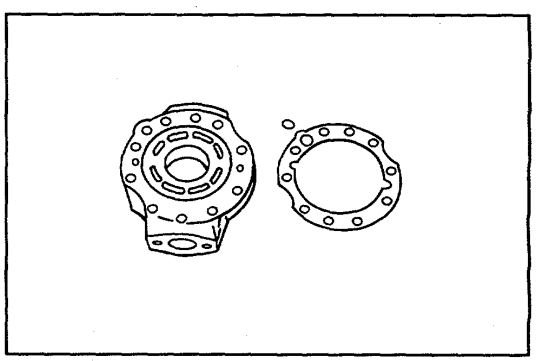


Figure 63

Install the end cap and valve plate, holding the valve plate so it does not drop off during assembly (refer to Fig. 64).

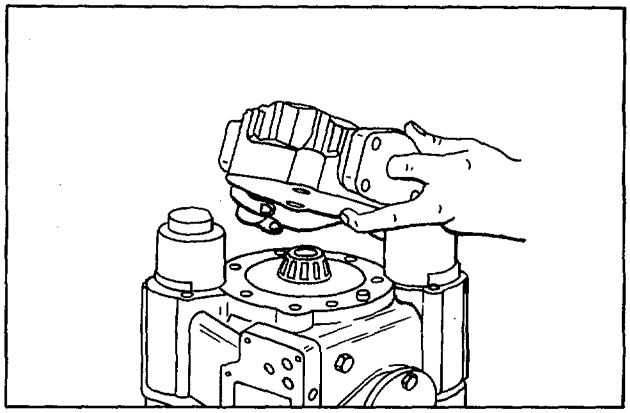


Figure 64.

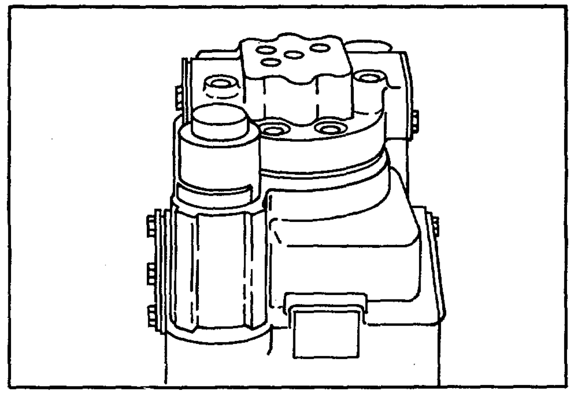


Figure 65.

The end cap will align with the housing mounting holes in one position only (refer to Fig. 65).

Install two screws and tighten alternately until the internal spring has compressed far enough for the end cap to rest on the housing. Install the remaining capscrews (refer to Fig. 66).

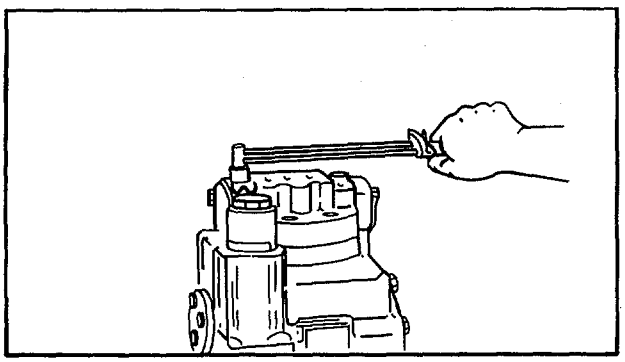


Figure 66.

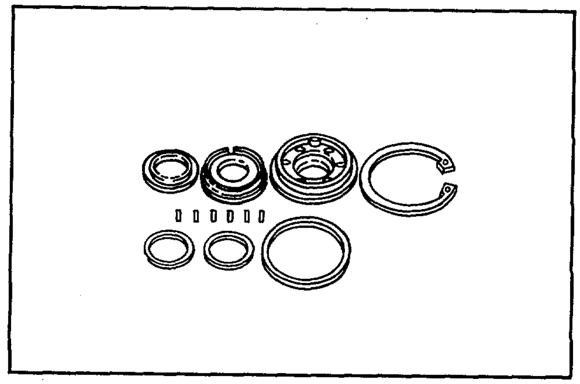


Figure 67.

Install the shaft seal as the last step in reassembly of the basic pump (refer to Fig. 67 and 68).

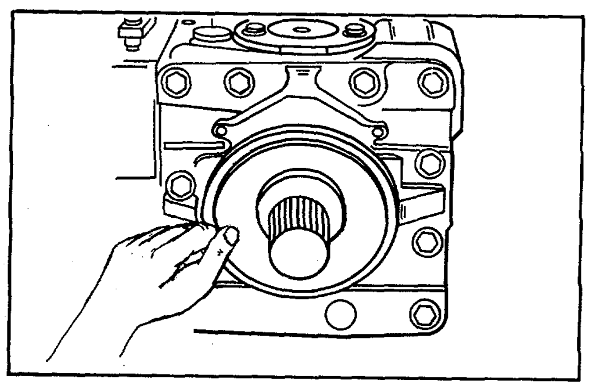


Figure 68.

Install the remaining major assemblies (control valve, check valves and charge pump) as outlined in *Minor Repair Procedures.*

CAUTION

Fill the pump housing with clean hydraulic oil.

PUMP PARTS IDENTIFICATION

GENERAL PARTS LIST

NO/LTR	DESCRIPTION	QTY.
A	Charge pump kit	1
B	Charge check valve kit	2
C	Servo housing kit	2
D	Servo piston kit	2
E	Cylinder block kit	1
F	Shaft seal kit	1
G	Displacement control kit	1
7	Screw-hex hd cap	3
8	Screw-hex hd cap	5
9	Washer-plain	8
10	End cap	1
11	Shim-bearing	AS REQ'D
12	Gasket-end cap	1
13	Bearing kit-rear	1
14	Pin-locating	2
15	Valve plate	1
29	Thrust plate	1
30	Screw	4
31	Retainer	2
43	Swashplate	1
44	Pin	2
45	Ring-retaining	4
46	Pin	1
47	Ring-retaining	2
48	Link-feedback	1
49	Shaft	1
50	Bearing kit-front	1
51	Gasket-front cover	1
52	Pin-locating	2
53	Front cover	1
54	Washer-plain	12
55	Screw-hex. hd. cap	12
65	Screw-hex. hd. cap	6
66	Washer-plain	6
67	Trunnion	2
68	Shims-trunnion	AS REQ'D
69	O-ring	2
70	Bearing kit-trunnion	2

This list is for identification of parts only. Specific model and part numbers are necessary to order replacement parts. For part numbers consult the Parts List for the specific model number.

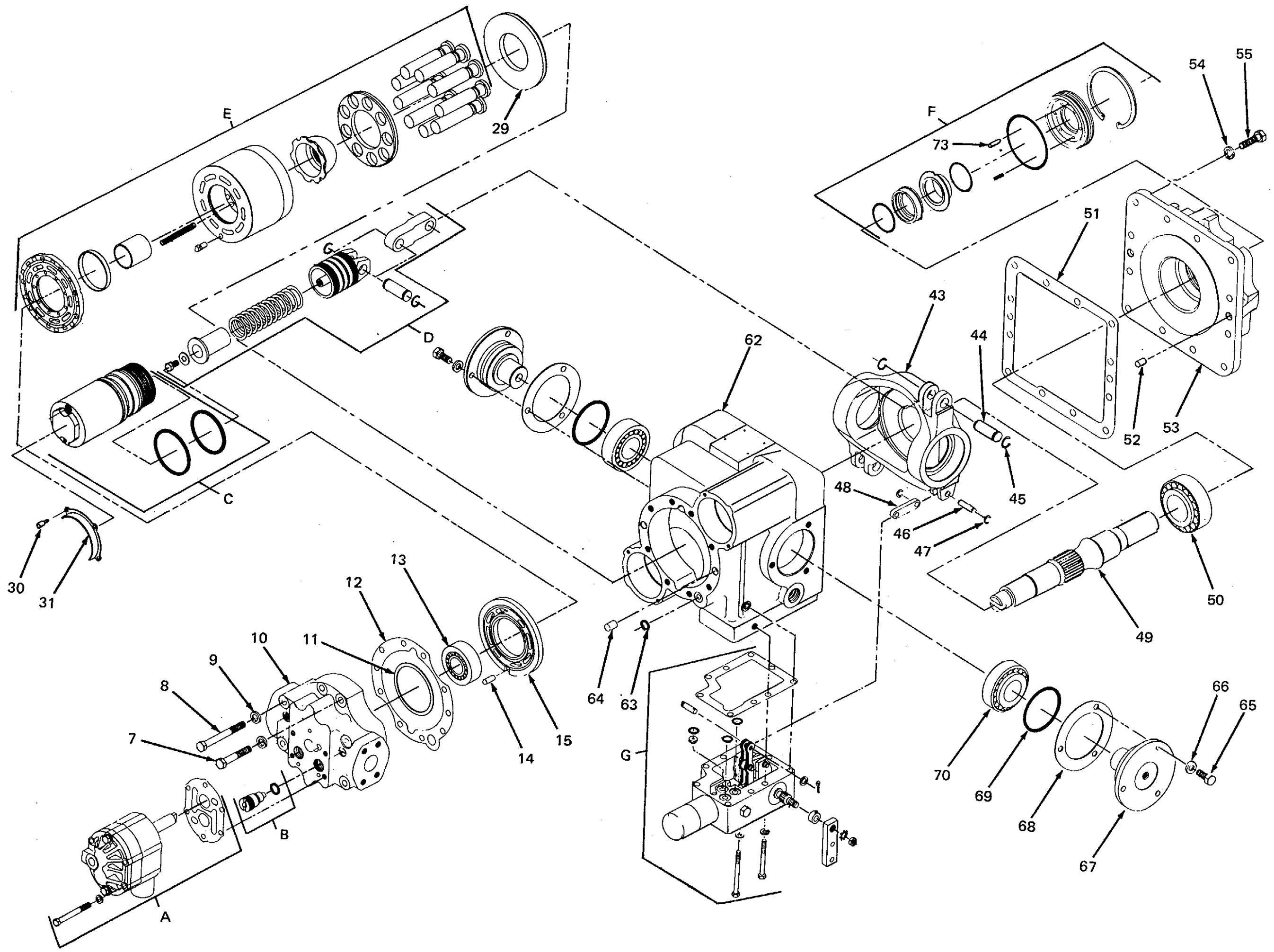


Figure 69. Variable Displacement Pump

TORQUE VALUES

INSTALLATION TORQUE VALUES (FT LB) BY SERIES

Location	20	21	22	23	24	25	26	27
Valve Manifold	16 21	16 21	16 21	16 21	16 21	16 21	16 21	16 21
End Cap	27 37	27 37	27 37	45 54	67 82	134 165	240 290	240 290
Charge Pump	10 11	10 11	10 11	10 11	27 37	27 37	27 37	27 37
Disp. Control	10 11	10 11	10 11	10 11	10 11	10 11	10 11	10 11
Check Valves	30 40	30 40	30 40	30 40	80 90	125* 135	125 135	125 135
Front Cover	27 37	27 37	27 37	45 54	67 82	67 82	67 82	67 82
Servo Spring	10 11	10 11	10 11	10 11	16 21	16 21	27 37	27 37

*Certain 25 series pumps (dash no. 9 or below) use smaller check valves which are torqued to 80-90 ft lbs

POWER STEERING

INTRODUCTION

Purpose of Manual

This manual is issued as the service publication for the Vickers' VTM27, VTM28, VTM40, VTM41, and VTM42 Series Power Steering pumps. These pumps may be identified specifically by model code shown on the name plate.

General

This manual contains service information for the proper operation, maintenance, and overhaul of all pumps covered by the model code shown in the *Typical Model Code Breakdown* table.

Physical and Operating Characteristics

The Vickers VTM27, VTM28, VTM40, VTM41, and VTM42 Power Steering Pump units are used primarily to supply a flow of hydraulic fluid for operation of power steering mechanisms. Pumps in this series are of the balanced vane-type and have a constant rate of delivery per revolution. Direction of pump rotation and pumping capacity may be changed to suit specific applications. The pumps are available with an integral reservoir or with a manifold for remote reservoir installations.

DESCRIPTION

General

The VTM27, VTM28, VTM40, VTM41, and VTM42 are identical in basic operation and performance characteristics, but have certain major differences involving reservoirs, pump volumes, mountings, and drive shaft configurations. The Typical Model Code Breakdown table illustrates a complete breakdown of the model number codes which cover all standard units in this model series. Special features are identified by a three digit suffix to the model number.

NOTE

Service inquiries should always include the specific model number which may be found on the pump name plate.

Assembly and Construction

The cutaway views of the pumps in this series illustrate the differences between these units. The VTM40 and VTM41 units are designed with integral reservoirs. The VTM27, VTM28, and VTM42 pumps have externally mounted reservoirs or can be adapted to manifolds for remote reservoir location. (The VTM42 is not shown but is similar to VTM27.) Principal components consist of the reservoir, body, cover, ring, rotor, vanes, pressure plate, relief valve, and drive shaft assembly. The VTM27, VTM41 and VTM42 Series pumps are designed for external mounting and indirect drives; however, special application approval must be obtained for gear drives.

NOTE

Helical gear drives must not be used with the VTM27 and VTM41 pumps.

The VTM28 and VTM40 Series pumps are designed for direct mounting. Most of the bearing load is carried by the external mounting. The VTM27, VTM28, and VTM42 units may be equipped with pump-mounted reservoirs or may be fitted with manifolds. (Refer to Fig. 7.) When manifolds are used, the pump is connected to a reservoir located elsewhere in the circuit.

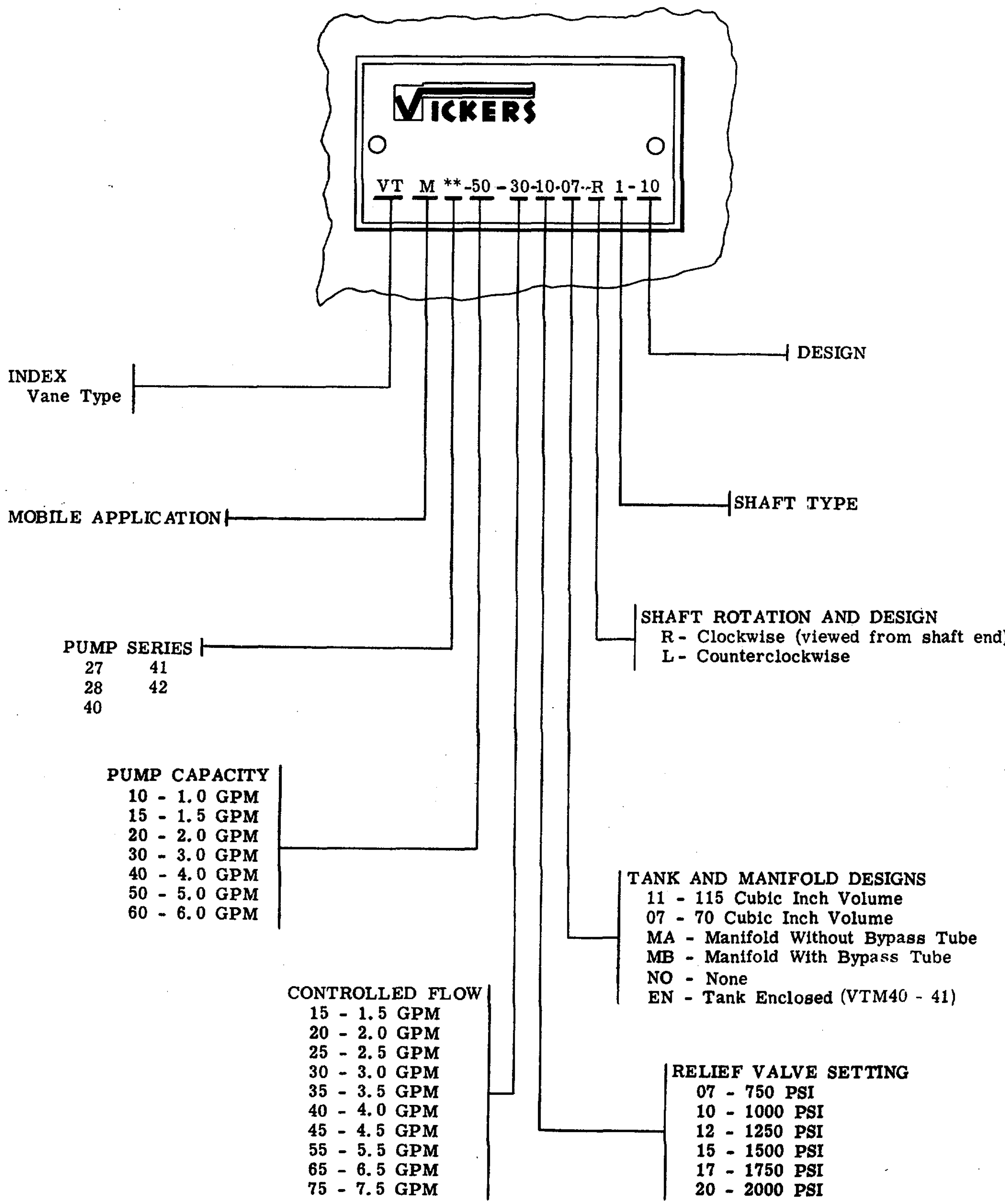
Flow Control and Relief Valves

These pumps are equipped with integral flow control and relief valves. Volume greater than the rated flow is bypassed to the inlet, within the pump through action of the flow control valve which operates on a pressure differential. The relief valve limits the maximum pressure in the hydraulic circuit.

Application

Consult Vickers Mobile Division application engineering personnel to determine correct pump ratings, methods of installation, and application.

TYPICAL MODEL CODE BREAKDOWN



OPERATION

Pump Operation

Pumps are composed principally of a pressure plate, ring, rotor, vanes, and wear plate. (Refer to Figs. 1, 2, 3, and 4.) The rotor is driven within the cartridge by a drive shaft, coupled to a power source. As the rotor speed increases, centrifugal action causes the vanes to follow the cam-shaped contour of the pump ring. (Fig. 5.)System pressure fed behind the vanes assures sealing contact of the vanes on the ring cam contour during normal operation.

The ring is shaped so that two opposing pumping chambers are formed, thus canceling any hydraulic loads on the bearings. Radial movement of the vanes, and rotation of the rotor, causes the chamber area between vanes to increase in size at the inlet (large diameter) section of the ring. This results in a low pressure, or vacuum in the chamber. This pressure differential causes oil to flow into the inlet, where it is trapped between the rotating vanes and is forced, through porting in the pressure plate to discharge into the system as the chamber size decreases at the pressure quadrant (small diameter) of the ring.

Flow Control and Relief Valve

Maximum pump delivery and maximum system pressure are determined by the integral flow control and relief valve in a special outlet cover used on pumps in this series. This feature is illustrated schematically in Fig. 6. An orifice in the cover limits maximum flow. A pilot-operated-type relief valve shifts to divert excess fluid delivery to tank, thus limiting the system pressure to a prescribed maximum.

Fig. 6 shows the condition when the total pump delivery can be passed through the orifice. This condition usually occurs only at low drive speeds. The large spring chamber is connected to the pressure port through an orifice. Pressure-in this chamber equalizes pressure at the other end of the relief valve spool and the light spring holds the spool closed. Pump delivery is blocked from the tank port by the spool land.

When pump delivery is more than the flow rate determined by the orifice plug, a pressure buildup forces the spool open against the light spring. Excess fluid is throttled past the spool to the tank port as shown in Fig. 6.

If pressure in the system builds up to the relief valve setting (Fig. 6), the pilot poppet is forced off its seat. Fluid in the large spring chamber flows through the spool and out to tank. This flow causes a pressure differential on the spool, shifting it against the light spring. All pump delivery is thus permitted to flow to tank.

Operating Instructions

Normally, these pumps require no manual priming. However, it is essential that, after starting, a minimum drive speed of 600 RPM be held until the pump picks up its prime and pressure is built up in the system. Failure to observe the above precaution can result in scoring and possible seizure of the pump due to a lack of oil for lubrication.

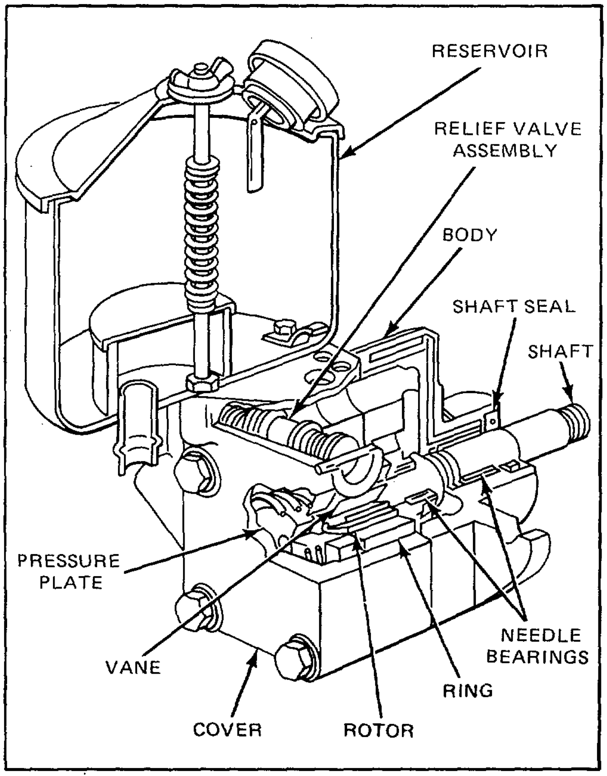


Figure 1. VTM27 Pump-Cutaway View

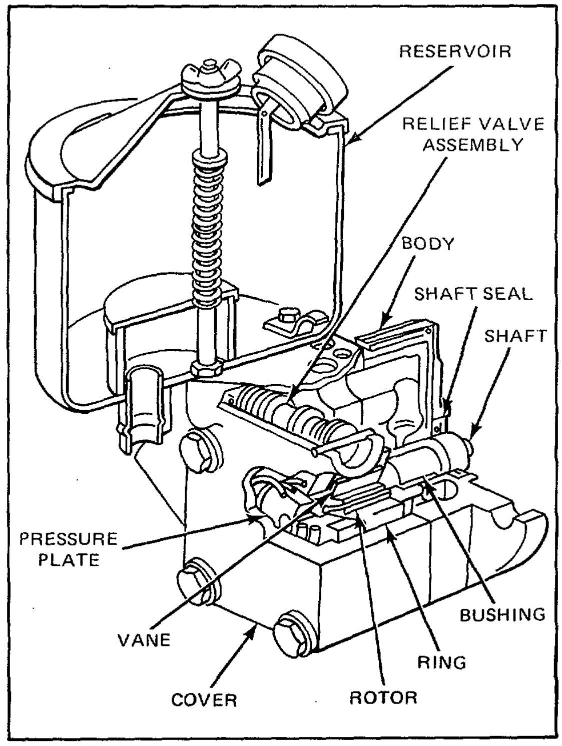


Figure 2. VTM28 Pump-Cutaway View

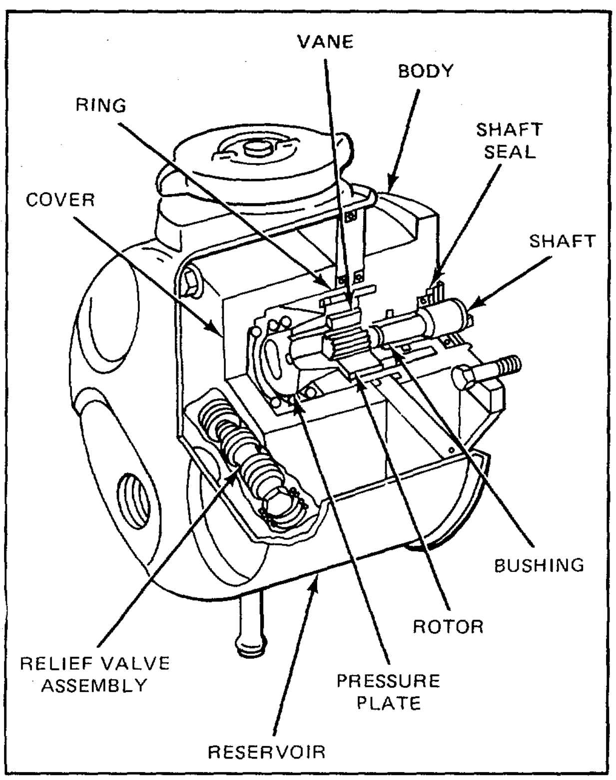


Figure 3. VTM40 Pump-Cutaway View

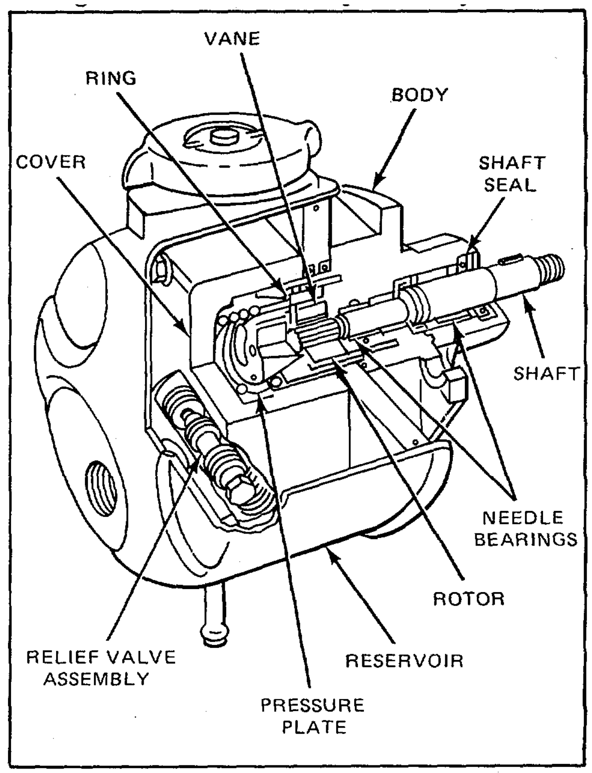


Figure 4. VTM41 Pump-Cutaway View

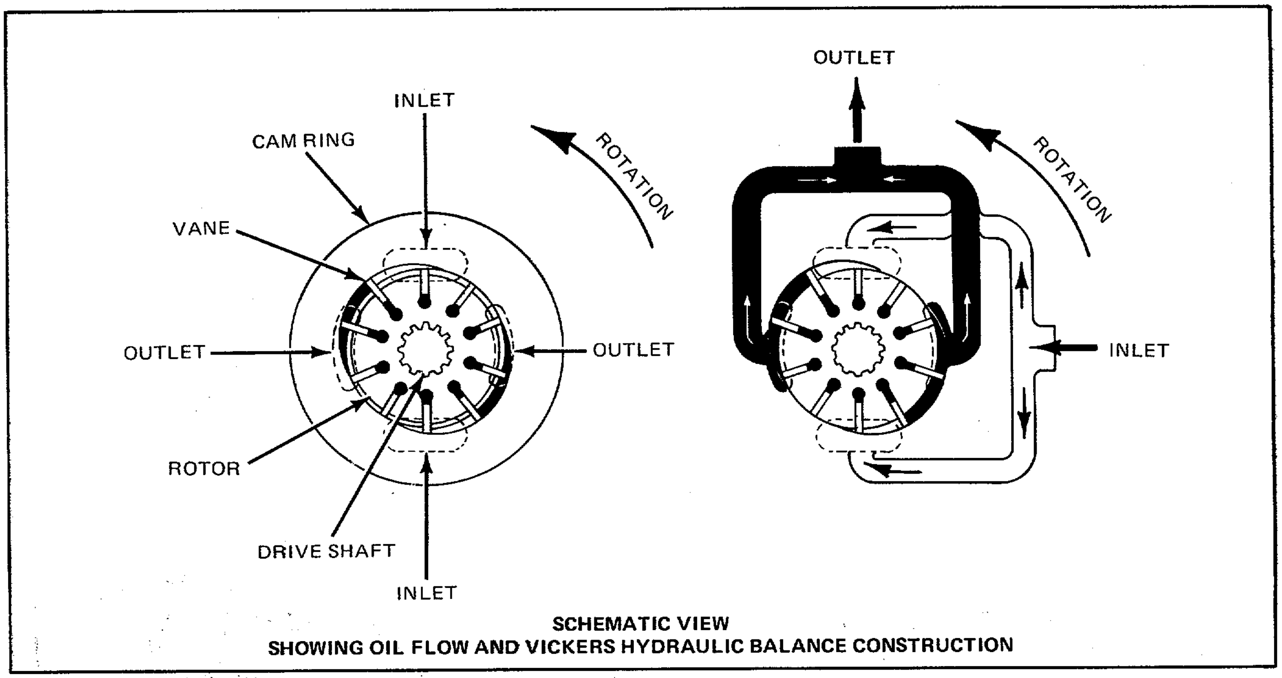


Figure 5.

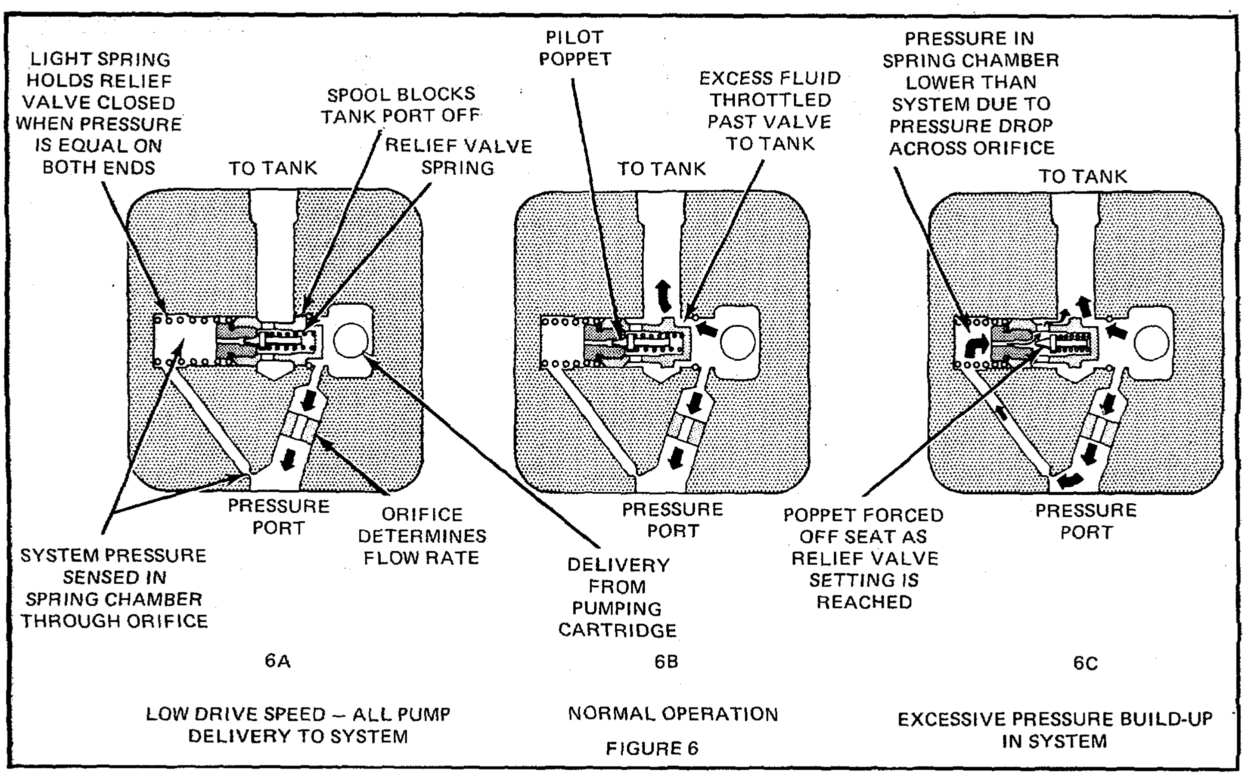


Figure 6.

CAUTION

Do not use hydraulic brake fluid. Use only high-grade oil of the viscosities recommended on Hydraulic Fluid Recommendations Installation. Do not use fire resistant fluids in Vickers' products without consulting Vickers' Mobile Division application engineering personnel. O-rings, seals, and packings which are compatible with petroleum-base fluids usually are not compatible with synthetic or water-base fluids.

INSTALLATION

Drive Connections

The VTM27 and VTM41 pumps are designed to be driven by belt, direct coupling, or spur gear. Helical gear drives must not be used. The VTM28 and VTM40 units must be mounted and coupled directly to an electric motor or generator. The VTM42 pumps have the same drive characteristics as the VTM27 and VTM41 pumps but are designed for heavier drive loads or thrust loads.

Exercise care in mounting these pumps to assure correct coupling shaft alignment with the power source.

When belts and pulleys are used, they must be properly aligned and adjusted to prevent excessive side loads on the pump shaft bearings.

Shaft Rotation

Pumps are manufactured for either right or left-hand rotation. They must be driven in the direction of rotation indicated by the arrow cast on the surface of the pump ring.

Direction of rotation may be changed by reversing pump ring and replacing with appropriate body and pressure plate. (See parts catalog and Overhaul.)Pumps may be damaged if driven in the wrong direction of rotation.

Hydraulic Tubing

Minimize the number of bends in tubing to prevent excessive turbulence and friction of oil flow in the circuit. Do not bend tubing too sharply.

The correct minimum radius for all bends is three times the inside diameter of the tube.

Use as few connections and fittings as necessary for proper installation to minimize possible leakage and flow resistance. Do not spring tubing into position. This will prevent undue strain at connections. Clean all tubing thoroughly before installation. Use approved methods such as sand blasting, wire brushing, or pickling to remove all dirt, rust, and scale.

Hydraulic Fluid Recommendations

Oil Type

Oils used in hydraulic systems perform the dual function of lubrication and transmission of power. Oil must be selected with care and with the assistance of a reputable supplier. Crankcase oils meeting or exceeding the Five Engine Test Sequence for evaluating oils for API (American Petroleum Institute) service MS (Maximum Severity) best serve the needs of mobile hydraulic systems. These engine sequence tests were adopted by the Society of Automotive Engineers, American Society for Testing Materials, and automotive engine builders. The MS classification is the key to selection of oils containing the type of compounding that will extend the operating life of the hydraulic system. Oils meeting Diesel engine requirements, DG and DS classifications, may or may not have the type of compounding desired for high performance hydraulic systems.

Good oils are the most economical. Specifications can be set up which will indicate, to a limited degree, the characteristics essential in a good hydraulic oil. These are listed herein and should be checked with the oil manufacturer prior to the use of his product.

Viscosity

Viscosity is the measure of fluidity. The oil must have sufficient body to provide adequate sealing effect between working parts of pumps, valving, cylinders, etc., but not enough to cause pump intake cavitation, sluggish valve action, or in extreme cases, resistance to flow. Viscosity recommendations must at best be a compromise, which takes into consideration the working temperature range, the type of hydraulic equipment used, and the class of service. Refer to table of oil viscosity recommendations below.

Viscosity Index

The viscosity index is a measure of the rate at which temperature changes cause a change in oil viscosity. It is very desirable that the oil viscosity remain as nearly constant as possible under the wide range of temperature conditions encountered in operating mobile and construction machinery. The viscosity index (V.I.) of hydraulic oil should not be less than 90 for this type of service.

Additives

Research has developed a number of additive agents which materially improve various characteristics of oils for hydraulic systems. They may be selected for compounding with a view toward reducing wear, increasing chemical stability, inhibiting corrosion, depressing pour point, and improving the antifoam characteristics. Proper use of additive agents requires specialized knowledge, and they should be incorporated by the oil manufacturer only, as serious trouble may otherwise result.

Most oil companies have several brands of crankcase oils of somewhat varying formulation that will meet the API service classification of MS. The more desirable of these oils for hydraulic service will contain higher amounts of the type of compounding that avoids scuffing and wear of cam lobes and valve lifters. These oils will also be formulated to be stable under oxidative conditions and when in contact with small amounts of moisture. There should also be reasonable protection against rust to any ferrous materials submerged in the oil or covered by the oil's film.

Cleanliness

Thorough precautions should be taken to filter the oil in the entire hydraulic system prior to its initial use to remove paint, metal chips, welding shot, lint, etc. If this is not done, damage to the hydraulic system will probably result. In addition, continuing filtration is required to remove sludge and products of wear and corrosion, throughout the life of the system.

Precautions should be taken in the de- sign of hydraulic circuits to assure that a means is provided to keep the oil clean. This can best be accomplished by the use of a 25-micron full- flow filter or a 10-micron bypass filter (not a strainer) and a micronic air breather or sealed reservoir.

Pump Inlet Conditions

Use of an improper grade of oil or restrictive inlet piping may result in inlet vacuum conditions exceeding the recommended maximum 5 inches of mercury, and will reduce the life expectancy of the hydraulic equipment. Where vacuum exceeds 5 inches of mercury, and it is not caused by improper oil selection, the Vickers Mobile Hydraulic Division is to be consulted for recommendations.

Operating Temperatures

Operation in excess of 180°F results in increased wear of the system components and causes more rapid deterioration of the oil.

The hydraulic system that is designed to maintain a temperature of 160°F or less is desirable.

Grade

Table I summarizes the oil types (viscosity and service classification) that are recommended for use with Vickers equipment. This selection is most important and should be made with considerable care.

TABLE I

Hydraulic System Operating Range (Min. to Max.)	SAE Viscosity	API Service Classi- fication
0°F. to 1800F.	10W	MS
150F. to 2100F.	20-20W	MS
320F. to 2300F.	30	MS
0°F. to 2100F.	10W-30	MS

These temperature ranges for each grade of oil are satisfactory if suitable procedures are followed for low temperature startup conditions and if sustained operation is avoided at the upper temperature limits. For optimum operation, a maximum oil viscosity of 4000 SSU at the low temperature startup condition and a minimum oil viscosity of 60 SSU for the sustained high temperature operating condition are recommended. Operation of the fluid at temperatures below 160°F is recommended to obtain the maximum unit and fluid life.

Automatic Transmission Fluid, Type A is usually satisfactory for power steering systems or those systems operating under moderate hydraulic service.

POWER STEERING

Miscellaneous

When starting temperatures are below 0°F consult the Vickers Sales Representative, Mobile Hydraulics Division of Vickers Incorporated.

These oil recommendations are made for the purpose of obtaining maximum service life and performance from hydraulic pumps and motors.

The performance of hydraulic valves and cylinders is less affected by the lubricating quality of the oil and, therefore, selection of the oil is less critical. It is always good practice, however, to use the best quality oil available for all components.

Overload Protection

Relief Valves

An integral relief valve on these units protects the pumps and other units in the hydraulic system from excessive pressures.

Relief Valve Adjustments Relief valves in the VTM27, VTM41, VTM42, VTM28, and VTM40 pumps are pre-set at the factory and no field adjustment should be made. If the relief valve setting must be changed, a replacement valve should be installed. (Refer to Parts Catalog.)

Pitman Arm Stops

Stops to limit the number of degrees that the Pitman arm can move in either direction should be installed with all pumps in this series. The stops should be properly adjusted to prevent excessive thrust and cramping of the steer- ing linkage which causes excessive pump relief valve operation.

SERVICE, INSPECTION, AND MAINTENANCE

Service Tools

No special tools, other than a shaft seal driver, are required to service these pumps. This driver should be used to assure installation of the shaft seal without damage. A length of tubular round stock should be machined to proper dimensions. The ends must be squared. The outside diameter of the tool should be slightly smaller than the outside diameter of the shaft seal. The inside diameter will be slightly larger than the shaft oil seal surface. The tool must be long enough so that the shaft is not contacted by the press installation of the seal.

Service Inspection

Daily Inspection

1. Make certain that all hydraulic connections are tight. A loose connection will allow fluid to escape or cause air to be drawn into the system resulting in noisy and erratic operation.

2. Inspect the hydraulic fluid in the reservoir for evidence of foreign particles. If contamination is found, the system should be drained.

Clean reservoir and filter thoroughly before refilling. Remove all lint particles to avoid possible clogging of system filters or strainers.

Refill the reservoir with new oil of the proper specification poured through a micron filter, or through a 200-mesh screened funnel.

Periodic Inspection

Check operation of the units against the troubleshooting chart. If pump is not operating satisfactorily, take the necessary corrective measures.

Maintenance

Removal Of Units

All openings in the circuit must be properly capped if units are removed. The units removed should also be capped or plugged to protect them from entry of foreign matter.

Adjustments

These pumps require no adjustments other than maintaining proper shaft alignment.

Replacement Parts

Use only genuine parts manufactured or sold by Vickers, Inc. as replacement parts for these units. Refer to Parts Catalogs.

Troubleshooting

The following troubleshooting chart is compiled on the basis of vane pump performance only. It lists the possible difficulties that may be en- countered and indicates the probable cause and remedy.

It must be remembered that many of the apparent failings in pump performance may be caused by other units in a hydraulic system. Improper pump operation is best diagnosed with adequate testing equipment and a thorough understanding of the complete hydraulic system.

TROUBLESHOOTING CHART

TROUBLE	PROBABLE CAUSE	REMEDY
PUMP NOT DELIVERING OIL	DRIVEN IN WRONG DIREC-TION OF ROTATION	Check direction of pump shaft rotation. Refer to *Operation* on *Flow Control and Relief Valve.*
	PUMP DRIVE SHAFT DISEN-GAGED OR SHEARED. BELT SLIPPING OR BROKEN	Remove pump; determine damage to cartridge parts (see dis-assembly instructions) re-place sheared shaft and needed parts.
	FLOW CONTROL VALVE STUCK OPEN	Disassemble pump and wash control valve in a clean sol-vent. Return valve to its bore and slide it back and forth. No stickiness in movement should occur. If a gritty feeling is noted on the valve O.D. it may be pol-ished with crocus cloth. Avoid removal of excess ma-terial or rounding of valve edges during this operation. Do not attempt to polish the valve bore. Wash all parts before reassembly of pump. Flush entire system thorough-ly and fill with clean oil as recommended in *Operation*.
	VANE OR VANES STUCK IN ROTOR SLOTS	Disassemble pump, examine ro-tor slots for dirt, grime or small metal chips. Clean rotor and vanes in a good grade solvent (mineral spirits or kerosene), reas-semble parts and check for free vane movement.
	OIL VISCOSITY TOO HEAVY TO PICK UP PRIME	Use fluid of the proper vis-cosity as recommended in oil data Table I.
	PUMP INTAKE PARTIALLY BLOCKED and refill system with clean oil as per recommendations.	Drain system completely; flush to clear pump passages. Flush

TROUBLE	PROBABLE CAUSE	REMEDY
PUMP NOT DELIVERING OIL (CONT'D)	AIR VENT FOR OIL TANK CLOGGED OR DIRTY STRAINER	Remove filler cap and clean air vent slot. Check filter or strainer in tank for clogged condition. Drain, flush, and add clean oil to system if strainer was clogged.
PUMPS MAKING NOISE	RESTRICTED OR PARTIALLY CLOGGED INTAKE LINE OR CLOGGED FILTER	Pump must receive intake oil freely or cavitation will result. Drain system, and clean intake line and strainers. Add new oil and strain by recommended procedures.
PUMPS MAKING NOISE	AIR LEAK AT PUMP INTAKE PIPING JOINTS OR PUMP SHAFT SEAL	Test by pouring oil on joints and around drive shaft. Listen for change in operation. Tighten joints affected and replace pump drive shaft seal according to service instructions outlined in this manual.
	COUPLING MISALIGNMENT	Realign and replace oil seal and bearings if damaged by shaft misalignment.
	RESERVOIR OR MANIFOLD SEAL LEAKAGE	Leakage between manifold or reservoir at replenishing hole due to O-ring damage. The reservoir inlet tube to pump cover O-ring should be carefully examined for damage such as cuts, nicks, or dirt.

PUMP OVERHAUL

DISASSEMBLY

CAUTION

Before removing unit or parts of unit to be serviced, be certain the unit is not subject to hydraulic pressure.

A puller must be used to remove pulley or gear from shaft. Otherwise bearing and shaft damage may result.

During disassembly, special attention should be given to identification of parts for proper reassembly.

Clean all parts except O-ring seals in a clean mineral solvent. Blow the parts dry with filtered compressed air. After drying thoroughly, lay the parts on a clean, lint-free surface. All internal oil passages of the pump cover, housing, and body must be thoroughly cleaned.

All O-rings, and the shaft seal should be replaced at reassembly. All seals should be soaked in hydraulic fluid before being used. Refer to Fig. 7 and proceed with disassembly.

Reservoir and Manifold

1. VTM40 and VTM41 Reservoir-The VTM40 and VTM41 pumps are tank enclosed units. To remove the reservoir from the pump, simply remove the discharge fitting, backup washer, and O-ring and free the reservoir from the pump.

2. VTM27, VTM28, and VTM42 Reservoir-Begin disassembly of VTM27, VTM28, and VTM42 pumps equipped with externally mounted reservoirs as follows:

Clamp pump mounting flange in a machinist's vise, being certain to use protective jaws. Remove wing nut, washer, cover, and gasket. Remove cotter pin

from reservoir stud. Lift flat washer, retainer spring, filter retainer, and filter element from stud. Remove reservoir stud and nut assembly. Remove the two capscrews, lockwashers, and baffle. Separate reservoir from pump and remove the O-rings from their seats in the cover.

3. VTM27, VTM28, and VTM42 Manifold-Begin disassembly of the VTM27, VTM28, and VTM42 units equipped with manifolds by removing the capscrews, copper washer, manifold, and O-rings from the pump cover.

Cover and Cartridge-Clamp pump mount- ing flange in a machinist's vise, being certain to use protective jaws. Remove cover mounting capscrews. Separate the cover from the pump body. Remove pressure plate spring and pressure plate. Remove adapter plate and O-rings (VTM40 and VTM41 units only). Remove pump ring, locating pins, rotor and vanes, and the two O-rings.

Mount the cover in a vise. Drive out retaining pin with pin punch. Protect the relief valve plug and subassembly against falling from bore. Work the plug, control valve, and spring from the bore.

NOTE

Access to the relief valve plug and subassembly may be gained through the large chamfered hole which leads to relief valve bore from inside the cover.

Wash all parts in clean solvent. Inspect relief valve and bore for wear and scoring.

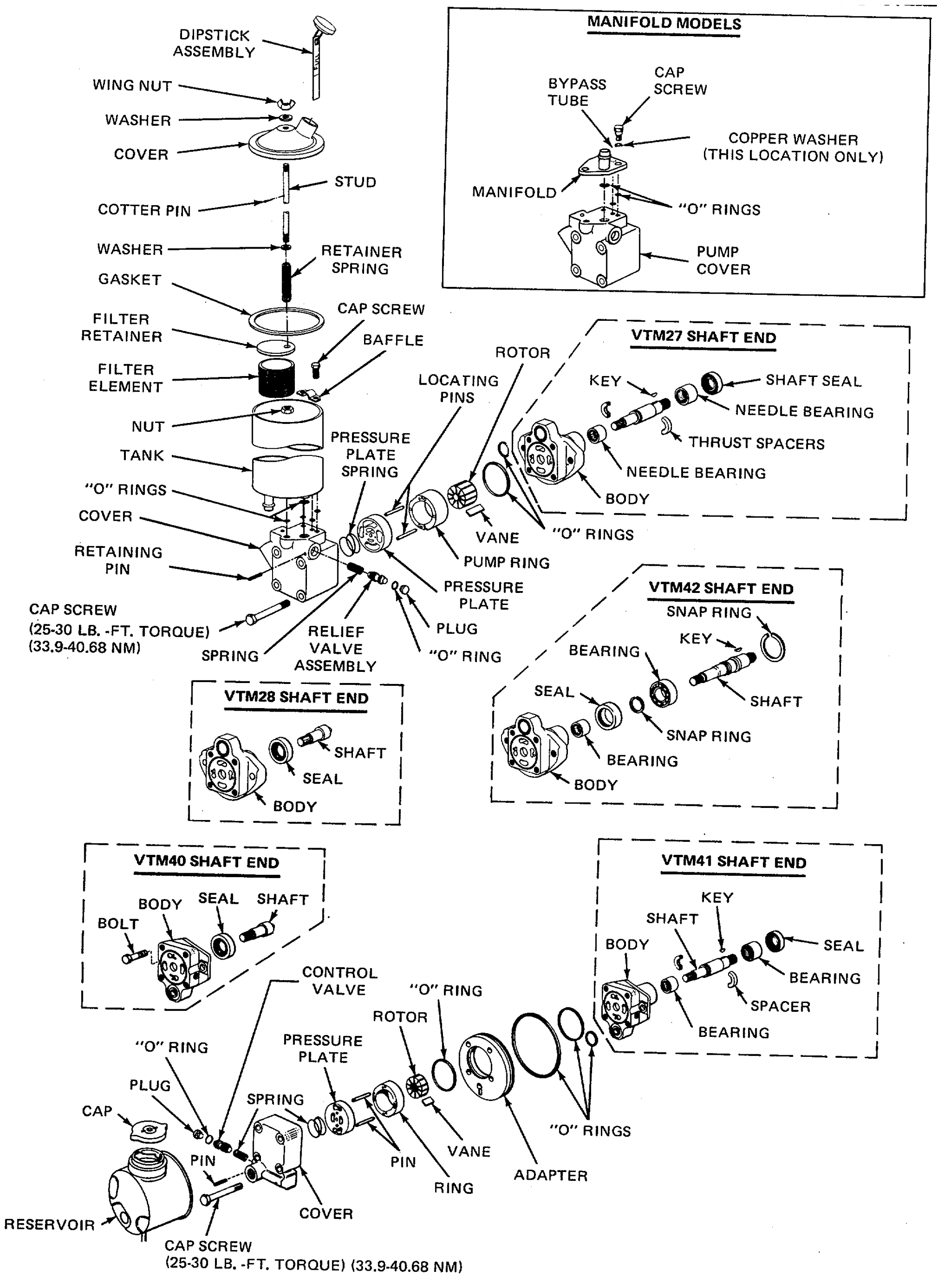


Figure 7. VTM27, VTM28, VTM40, VTM41, and VTM42 Pump Exploded Views

Shaft End

1. VTM27 and VTM41-Support the shaft end of the pump body in a two- inch straight pipe coupling and, using an arbor press, remove the shaft thrust spacers, outer needle bearing, and shaft seal. The shaft assembly should drop through a slot in the press table so the shaft will not be damaged. The outer needle bearing and shaft seal are a press-fit to the body. Use a pin punch and hammer to tap the inner needle bearing from the body.

2. VTM28 and VTM40-Remove the shaft and seal from the pump body. The shaft bushing is included in the body subassembly and cannot be serviced separately.

3. VTM42-Remove the large snapring that retains the outer ball bearing in the body. Press the shaft and outer ball bearing from the body. Remove the inner, small snapring that retains the outer ball bearing and remove bearing from shaft. The inner needle bearing and shaft seal are a press fit to the body. Use a pin punch and hammer to tap them from the body.

INSPECTION, REPAIR, REPLACEMENT

NOTE

Wash all parts, except seals, in clear mineral solvent and lay them aside for inspection. Replace all old seals and O-rings at reassembly.

Ring, Rotor, Vanes, Pressure Plate, Body-Inspect the surfaces of all parts which are subject to wear. Light scoring may be removed from the faces of the body or wear plate with crocus cloth (by placing the cloth on a flat surface), medium India stone or by lapping. Check the edges of vanes for wear. Vanes must not have excessive play in slots or burrs on edges. Re- place if necessary. Check each rotor slot for sticky vanes or wear. Vanes should drop in rotor slots by their own weight when both slot and vane are dry.

Relief Valve-Insert valve in its bore in pump cover. There should be no binding. Check valves and bore for excessive wear and scoring. Replace if necessary.

Bearings-Wash bearings and shaft assembly thoroughly. Bearings must be replaced (VTM27, VTM41, and VTM42 only) if they are removed for any reason. The shaft bushing cannot be serviced on VTM28 and VTM40 Pumps. If the bushing becomes worn, replacement of the body subassembly must be made.

Shaft and Seal-Replace the shaft seal at each overhaul to prevent oil leak- age. Check the drive shaft oil seal diameter for wear and scoring. Do not install a new seal on a shaft which is worn or damaged at the oil seal diameter. Replace the shaft if worn. Stone and polish the sharp edges on the shaft to prevent damage to the seal.

Body and Cover-Stone all mating surfaces with a medium India stone to remove all burrs and sharp edges. Rewash all parts after stoning.

REASSEMBLY

NOTE

Immerse all parts in clean hydraulic oil to facilitate reassembly.

Shaft End

1. VTM27 and VTM41 Pumps-Press inner needle bearing in the body, using an arbor press.

2. Assemble the split-ring thrust spacer on the shouldered portion of the shaft and install shaft in the pump body.

3. Press outer needle bearing onto shaft. The edge of the bearing must be 1/64 inch below the shaft seal shoulder when assembled. This provides for shaft end play of approximately .010 to .015 inch.

NOTE

Tools for installing bearings can be made from round stock the outside diameter of which is slightly smaller than the outside diameter of the bear- ing and the inside diameter slightly larger than the shaft diameter. Do not score or otherwise damage the shaft during this operation.

4. Position the seal on the shaft- end of the body, being careful not to damage seal. Using special tool, (refer to Service Tools in Service, Inspection and Maintenance) press seal in until it engages the shoulder in the body. This shoulder acts as a positive stop for the seal. Do not overpress as damage to the seal will result.

5. VTM28 and VTM40 Pumps-Carefully install shaft to prevent damage to shaft bushing and oil seal surfaces.

6. VTM42 Pumps-Press inner needle bearing into the body with an arbor press. Install shaft seal in the body in the same manner. Press outer ball bearing on shaft and assemble small snapring onto shaft. Install shaft assembly in the body. Insert large snapring in body to retain ball bearing.

Cover and Cartridge

1. Install locating pins in pump body. Install ring over pins in correct direction of rotation.

2. Install rotor with chamfered edge of splined hole in or toward pump body. The chamfer facilitates assembly.

3. Install vanes with their radius edge toward the inner ring contour.

4. Install the adapter plate and O-rings. (VTM28 and VTM40 only.)

5. Oil the cartridge with clean hydraulic oil and install pressure plate.

6. Install O-rings. Install pressure plate spring and cover. Tighten cover screws to 25-30 ft lb torque.

7. Install pressure-compensating spring in relief valve bore. Insert valve assembly with the hex toward the spring. Install plug with O-ring in bore and hold it in position while driving a new retaining pin.

Reservoir and Manifold

1. VTM27, VTM28, and VTM42 Reservoir-Install O-rings on reservoir mounting pad on cover. Position reservoir on pad, being careful not to unseat O-rings. Install capscrews, washers, and reservoir stud and lock-nut. Install filter element. Be certain it is located over reservoir return tube orifice. Install filter retainer spring, flat washer, and cotter pin. Install reservoir cover, gasket, washer, and thumb screw. Replace dipstick assembly. Rotate pump shaft by hand to check for free operation of pump.

2. VTM27, VTM28, and VTM42 Manifold-Install O-rings in pump cover and secure manifold to pump body with screws. Copper washer is used on screw where tapped hole enters oil passage.

3. VTM40 and VTM41 Reservoir-In- stall the two pump mounting bolts in the body flange on VTM40 models. In- stall a new O-ring on adapter plate. Install reservoir so the hole is aligned with the cover discharge port. Install a new O-ring on the discharge fitting and install fitting to secure reservoir. Be careful that the O-ring is not damaged as it is forced through the hole in the reservoir.

PUMP TESTING

Vickers Mobile Division application engineering personnel should be consulted for recommendations on test stand circuit requirements and construction. If test equipment is available, pumps should be tested at speeds and pressures shown on installation drawings.

STEERING CONTROL

Your Orbitrol power steering control has been designed and manufactured with the greatest care to sustain all parts in peak operating condition throughout a long period of trouble-free service. As are many hydraulic components, the Orbitrol is continuously lubricated by the fluid which is used to power the system. A good selection of adequate materials allows the unit to function well over a wide temperature range.

The Orbitrol is specifically designed for use with automatic transmission fluid, Type A. All standard units, unless otherwise specifically ordered, have synthetic seals which are compatible with ATF-A at temperatures up to over 200°F.

A normal periodic functional check of the entire vehicle power steering system will generally be adequate to insure satisfactory service. The oil level of the reservoir that supplies the system is most important. If the oil level drops appreciably over short periods of use, it will be wise to search for a leak in the system.

A black accumulation of dirt at a fitting can indicate a leakage point. If the fitting is taken apart to correct leakage, first clean the area complete- ly with a solvent-wetted cloth, steam clean, or otherwise clean off any debris from the immediate area and any dirt accumulation above the area so that contamination will not enter the system while the connection is open. Then be extremely careful to apply compound sparingly to the male fitting only. Do not let any compound enter an area in which it may be washed into the oil stream.

WARNING

Never use fluid system stop leak additives to attempt to seal fluid leakage. Many good automotive power steering systems have been ruined by such attempts.

To continue the functional check of the system, turn the steering wheel through the full travel with the vehicle power on. Do this at engine idle and full throttle with the machine standing still, the steered wheels on dry concrete, and with the machine rolling slowly. Note any speed irregularities and sticky sensation. These may indicate dirt in the fluid. If under any of these conditions the steering wheel continues to rotate when started and released, a condition known as motoring exists. This may also indicate dirty fluid in the system.

If a dirty fluid is suspected, clean or replace the filter element in the system. This is generally located in or near the pump or reservoir.

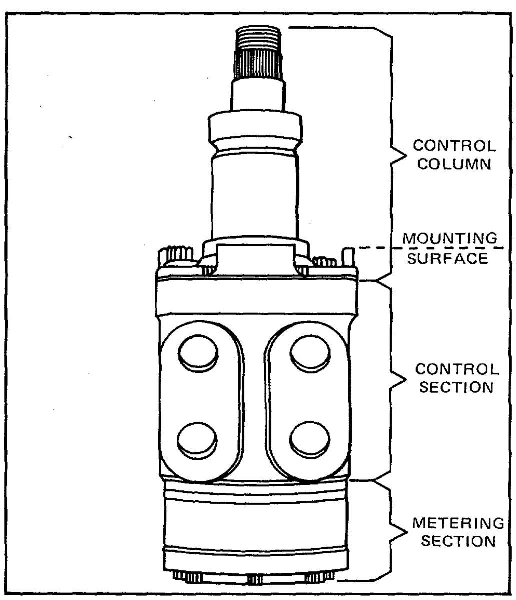


Figure 1.

There is no filter in the Orbitrol. Drain and replace as much of the oil as possible. Crank the pump over by hand to exhaust oil from it and swing the cylinder through a full travel; but do not forcibly rotate the Orbitrol steering wheel if a dirty fluid is suspected. Refill the system with clean oil, run the system briefly, recheck, and refill as necessary to obtain proper fluid level. Operate the system for a short time to determine whether a correction has resulted. It is sometimes less costly to rinse and reclean the system twice than to completely tear down and reassemble a unit and the clean fluid will definitely protect all of the components of the system.

In the functional check, also determine that the actuating cylinder achieves full travel without hesitation. If the cylinder seems to pause in its travel while it should be moving smoothly, this may indicate that it contains trapped air. In filling and refilling a system, it is sometimes necessary to lift the vehicle weight off the steered axle or to remove the cylinder and hold it in a position so that the ports are uppermost. In this position air will be bled back to the system reservoir and effectively exhausted from the system at the reservoir vent. During this inspection, determine that the mechanical or other limit stops at the axle are functioning properly. Proper wheel alignment is every bit as important on power-steered vehicles as on any other to insure satisfactory tire life and geometrically true steering.

Inspect to insure that the system has adequate power. Some machines are designed so that they cannot be steered unless they are rolling. Most, though, will steer completely while standing still on a smooth, hard surface. If there is an indication of hard-steering, this can indicate either a reduced oil flow to the control or a reduced system relief pressure.

Adequate oil flow under all conditions can best be checked by timing the full travel of the cylinder with the steered axle unloaded and loaded. If there is a great difference at low engine and slight difference at high engine speed, this may indicate a defective pump drive. Adequate oil pressure can only be determined by connecting a pressure gauge (2000 psi full scale recommended) at the pump outlet port or at the IN port of the Orbitrol. With the engine running at a medium speed, turn the steering wheel to one end of the travel and hold the cylinder at the travel limit just long enough to read the pressure gauge.

CAUTION

> Never hold a system at relief pressure for more than a few seconds at a time. Longer operation at relief pressure can overheat most systems quite rapidly. The pressure relief valve is a protection for all of the various parts of the steering system. There is no pressure relief in the Orbitrol. Power steering pressure relief valves are usually located in the power steering pump or flow control valve or very near the discharge line of either of these. Check or adjust to the vehicle manufacturer's recommended pressure setting.

If the system is reported to operate extremely hot, connect a pressure gauge as above and operate the engine at near full throttle. Rotate the steering wheel slowly in each direction and bring the wheel to the position that shows the lowest pressure reading. This places the control section of the unit in neutral. Then turn the steering wheel to a limit stop and hold it there for one to two seconds. Release the steering wheel gently and watch the gauge.

If the pressure does not drop to very nearly the same neutral pressure as measured when placing the control in neutral deliberately, a binding control shaft or dirt between the spool and sleeve of the control valve can be the cause of difficulty.

If the recentering characteristic as measured above is erratic and if the control feels slightly sticky through most of the travel, apply the pressure gauge in the OUT line of the Orbitrol. This return line pressure should be below 30 psi during all periods of normal operation. Check this downstream line to insure that no fittings are obstructed. If the system uses a return line filter, as in many common power steering pump-tank units, a higher return line pressure may indicate that the filter needs cleaning.

If you need or wish to accomplish repairs within the unit, use the following procedure for disassembly, inspection and reassembly.

STEERING CONTROL REMOVAL

Before removing the Orbitrol from the vehicle, be certain that the unit, its surrounding area, and the connecting lines are cleaned free from dirt and contamination. If the vehicle must be moved while the steering control is off, you will need two 3/8 pipe elbows if the unit is connected with hose or four elbows and two close nipples if it is connected with tubing. Use the fittings to couple the IN to the OUT line and the L to the R line when these are removed from the unit. If it is necessary to remove the steering wheel, make sure to use a wheel puller. Do not hammer the end of the shaft or the steering wheel nut because this disrupts the upper column bearing which is designed to allow the critical freedom required for satisfactory function. If you must use a hammer, order a spare bearing and snaprings first.

On some machines it may not be necessary to remove the upper column. Remove the two mounting screws and lower the entire assembly far enough to provide access to the two screws which fasten the column to the lower unit.

Observe the shaft area of the lower unit immediately upon removal of the column assembly. If it shows an appreciably oil-wetted appearance this indicates that the shaft seal may have been leaking.

If there is a functional problem or leakage at the control end of the unit only, the disassembly of the control end of the unit only will be required and it is generally advisable to leave the seven-bolted end assembled.

If a complete tear down and reassembly of the unit is planned, clean all paint and surface contamination from the unit at points of separation. This is extremely important at the meter end of the unit so that no paint flakes or particles will enter these closely fitted parts as they are being reassembled. To clean the unit adequately, first plug all four ports, then wire brush around the meter area and rinse and blow away all surface contamination before any disassembly is begun.

For any disassembly, an extremely clean bench area is necessary. Do not use shop cloths or cotton waste to wipe or clean the parts. The lint deposited by these can disrupt function or cause leaks. The clean inside surface of a corrugated container is frequently a very adequate assembly surface.

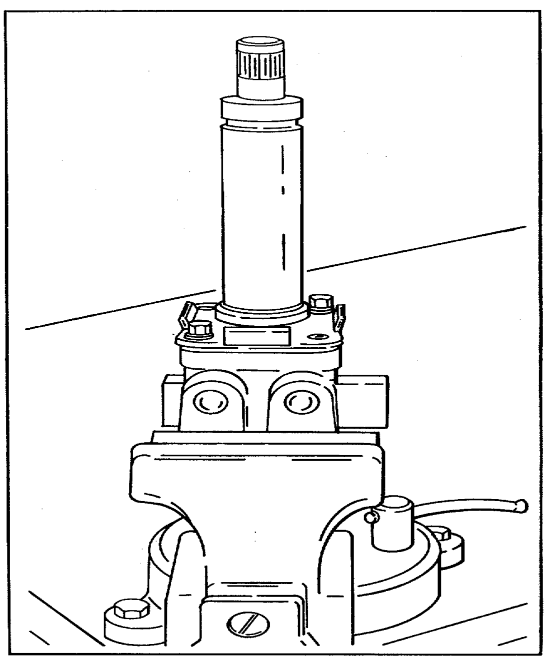


Figure 1.

Assembly is generally easier and more satisfactory with clean, dry parts. After parts are rinsed clean in solvent they may be blown dry with an airhose or placed on clean paper towel to drain and air dry.

If parts are thus prepared as they are removed, they are frequently ready for reassembly by the time they are needed.

NOTE

The following procedure applies to all units with Model numbers starting with U or W. They can be identified by a one-piece housing and a check hole plug with an O-ring at about the middle of the O.D.

STEERING CONTROL DISASSEMBLY

Place the unit in vise, control end up. Clamp across port surface and opposite side of housing lightly. Remove the two capscrews that fasten column to lower unit. Remove column and set aside. (Mark the two capscrew holes so that the ports will be in the proper direction when reassembled.) (Refer to Fig. 1, 2, and 3.)

Clamp unit in vise across mounting plate edges with meter end up and remove seven capscrews (refer to Fig. 4).

Remove control assembly from vise and check for free rotation of the control spool and sleeve parts with column shaft (refer to Fig. 7).

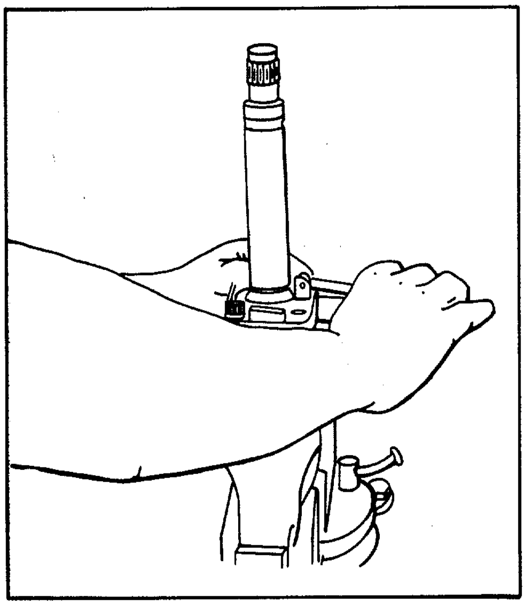
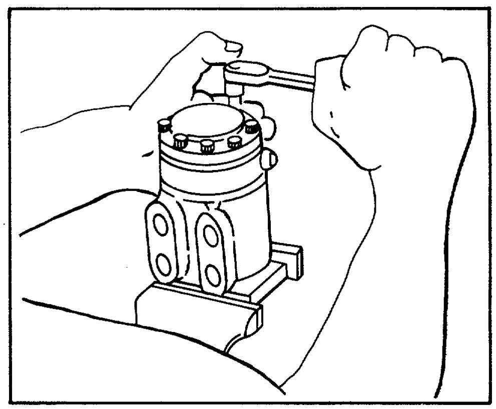


Figure 2.



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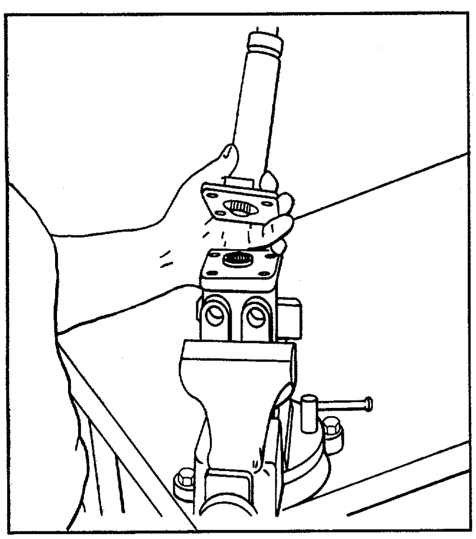

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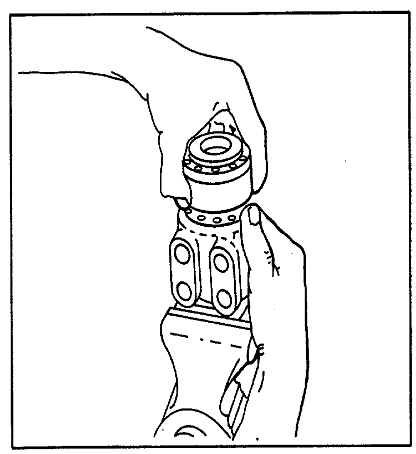

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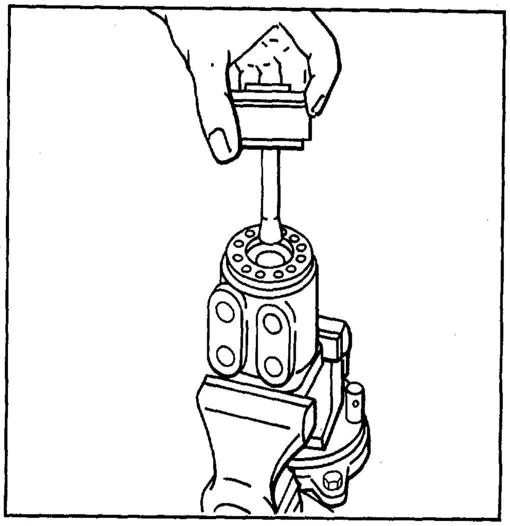

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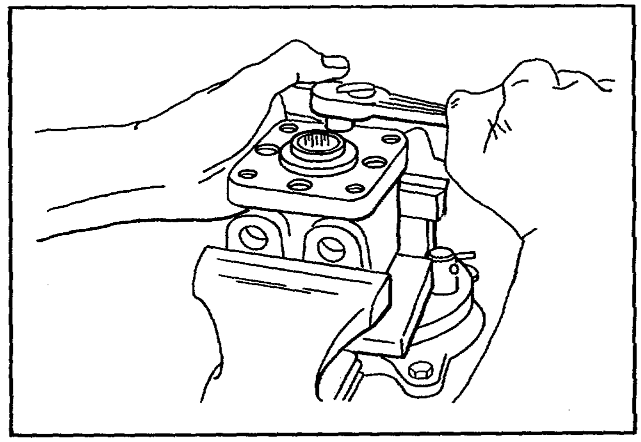

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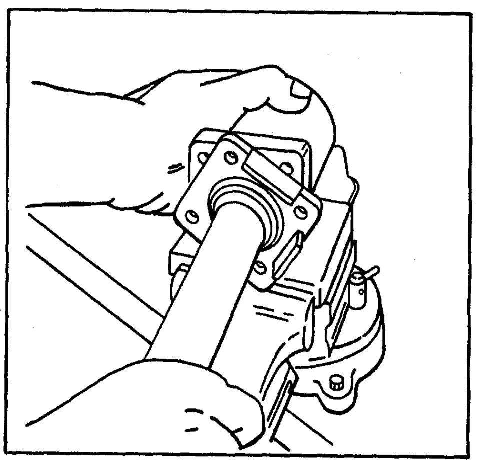

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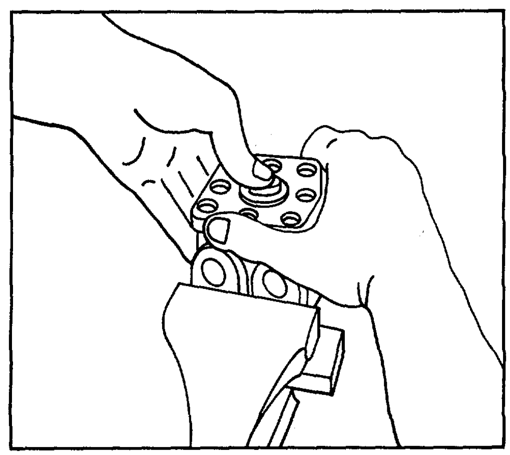


Figure 9.

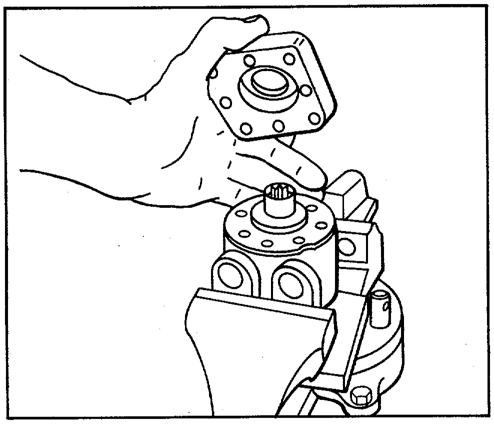
Place clean woodblock across vise throat to support spool parts and clamp unit across port face with control end up. Remove and set aside four capscrews (refer to Fig. 8).

Hold spool assembly down against block in vise and lift off end cap (refer to Fig. 9).

Inspect mating surfaces for obvious leakage path, wear, and seal condition (refer to Fig. 10).

Remove cap locator bushing (refer to Fig. 11).

Place housing on solid surface with port face down so that it can be held securely and remove spool-sleeve assembly from the 14-hole end of housing (refer to Fig. 12).



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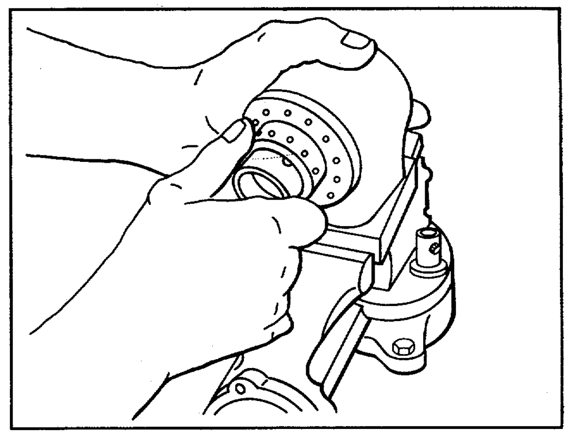

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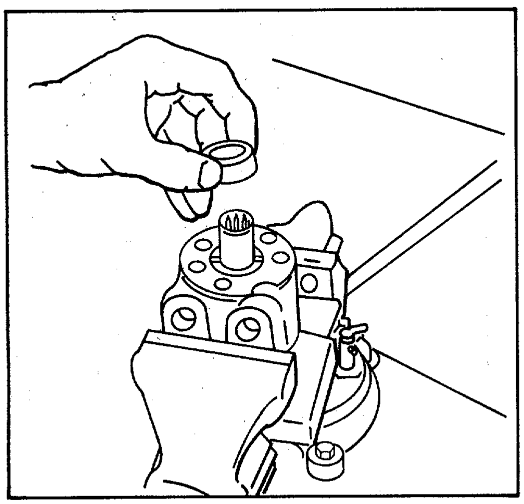


Figure 11..

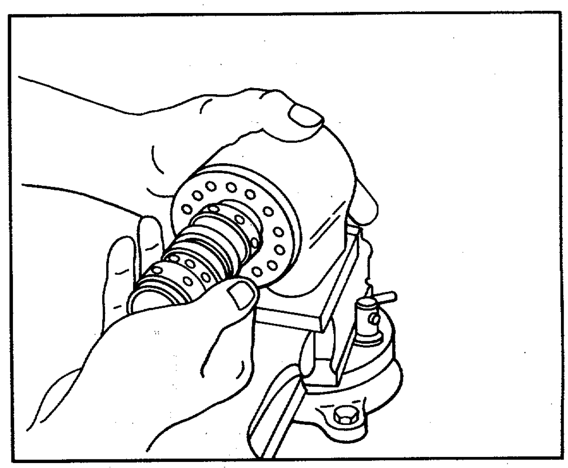
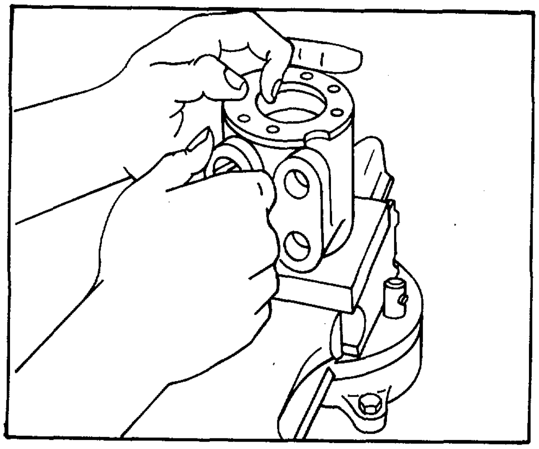


Figure 13.

Be extremely careful to prevent these parts from binding as they are very closely fitted and must generally be rotated slightly as they are withdrawn (refer to Fig. 13).

Using a small, bent tool or wire, the check valve seal plug can be removed by pushing on it, reaching it through the out port. Do not pry against edge of hole in housing bore (refer to Fig. 14).

Place housing in vise, control end up, and unscrew check valve seat with 3/16 hex wrench (refer to Fig. 15).



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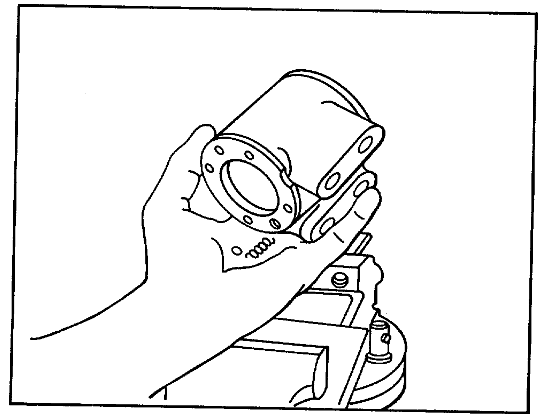


Figure 16.

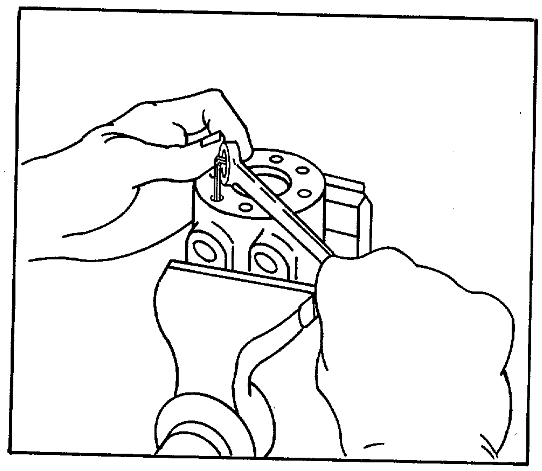


Figure 15.

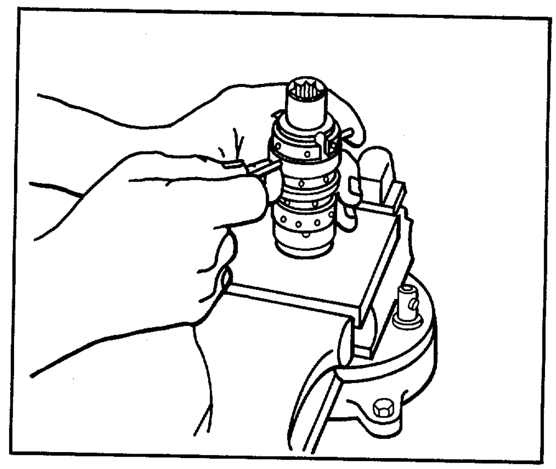


Figure 17.

Upend the housing and tap slightly with butt of hand. Hold check valve hole toward lowest corner and remove check valve seat, ball, and spring (refer to Fig. 16).

In spool assembly, push the cross pin to loosen from spool sleeve assembly (refer to Fig. 17).

Remove cross pin and set aside (refer to Fig. 18).

Push the inside, lower edge of spool so that spool moves towards splined end and remove carefully from sleeve (refer to Fig. 19 and 20).

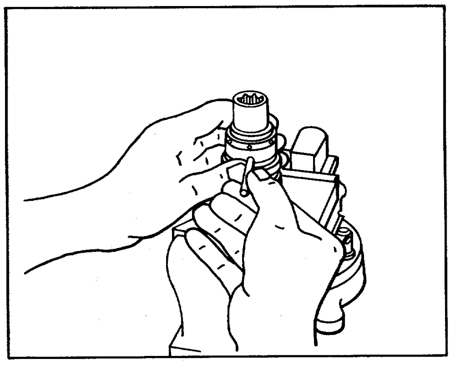


Figure 18.

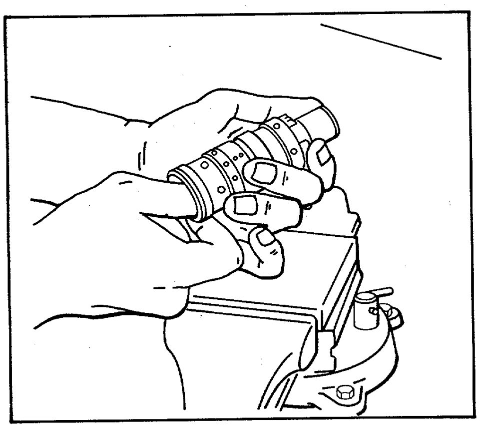


Figure 19.

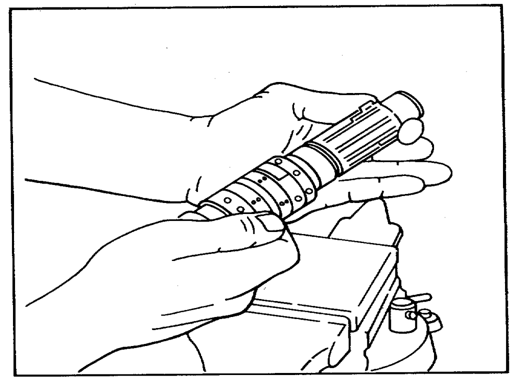


Figure 20

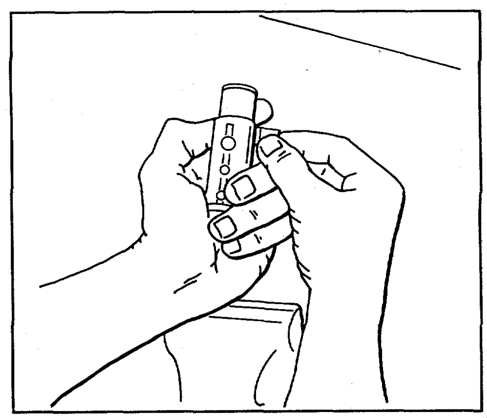


Figure 21

Push centering spring set out of spring slot in spool (refer to Fig. 21 and 22).

At this point all parts have been disassembled and removed from the unit. Each should be rinsed carefully in clean solvent, even such exterior parts as all capscrews and all seals that appear to be reusable. If in doubt, replace with new seals. It is good service policy to replace all seals when unit is reassembled. They are available in kit form, part no. 5140. Rinsing and cleaning can be done while other parts of the unit are being dis- assembled and parts can be set to dry on clean paper towel. The meter gear set must be disassembled and cleaned similarily.

Inspect all moving surfaces to insure that they have not been scored or abraded by dirt particles or otherwise disrupted. Smooth burnished surfaces are normal in many areas. Slightly scored parts can be cleaned with 600-grit abrasive paper by hand rubbing only.

To prepare all surfaces of the meter section for reassembly and insure that all edges of the parts are burr-free, place a piece of 600-grit abrasive paper faceup on an extremely flat, clean, hard surface. The surface to be used for this purpose should be as flat as plate glass or better. If the 600- grit paper is new, it should first be rubbed down with a scrap steel part to remove sharp grit which would produce scratches. The ends of the star gear can be used for this purpose if necessary. Then both sides of the ring gear, both sides of the plate, the 14- hole end of the housing and the flat side of the end cap should be cleaned lightly.

Stroke each surface across the abrasive several times and observe the part (refer to Fig. 23). Any small, bright area near an edge indicates a burr which must be removed. Hold the part so that contact with the abrasive is as flat as possible. (Do not push one edge down hard or the flatness will become rounded.) Check each part after 6 to 10 strokes across the abrasive. After polishing each part, rinse clean in solvent and blow dry. Keep these parts absolutely clean until they are assembled.

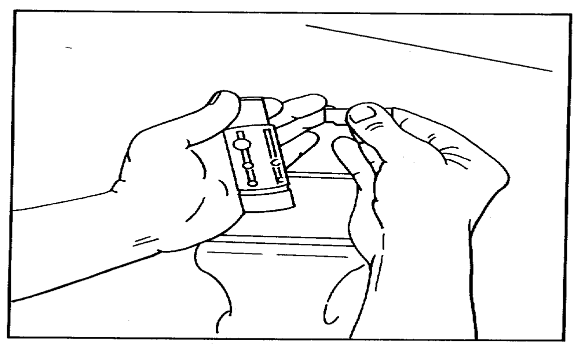


Figure 22.

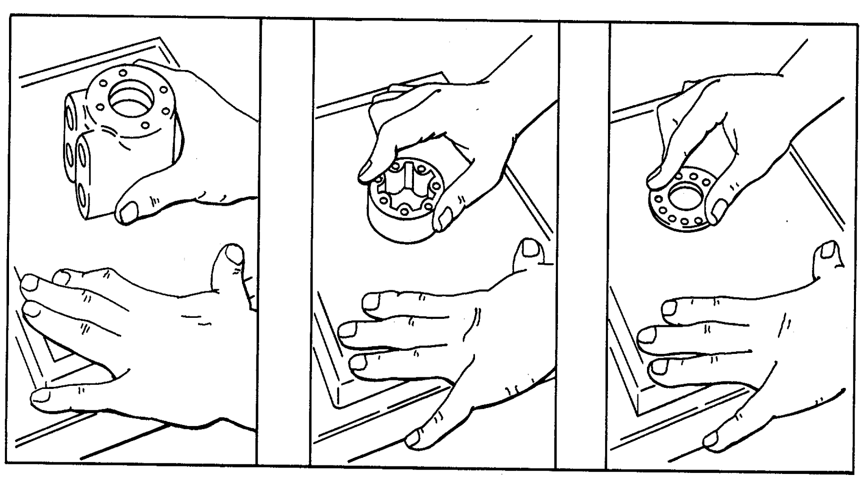


Figure 23.

STEERING CONTROL REASSEMBLY

Place housing in vise with control end up. Protect 14-hole end as before, and clamp across port surface lightly. Drop check valve spring into check hole with large end down (refer to Fig. 24).

Drop check ball into check hole and insure that it rests on top of the small end of the spring within the hole (refer to Fig. 25). Place the check valve seat on hex wrench and screw into threads within check hole so that the machined counterbore of the check seat is towards the ball (refer to Fig. 26).

Tighten check seat to 12.5 lb ft (16.94 Nm) torque. (Refer to Fig. 27.) Test check ball action by pushing ball with small clean pin against spring force. Ball need not be snug against seat for proper function.

Install spool within sleeve carefully so that spring slots of both parts will be at same end. Rotate while sliding parts together. (Refer to Fig. 28 and 29.) Test for free rotation. Spool should rotate smoothly in sleeve with fingertip force applied at splined end.

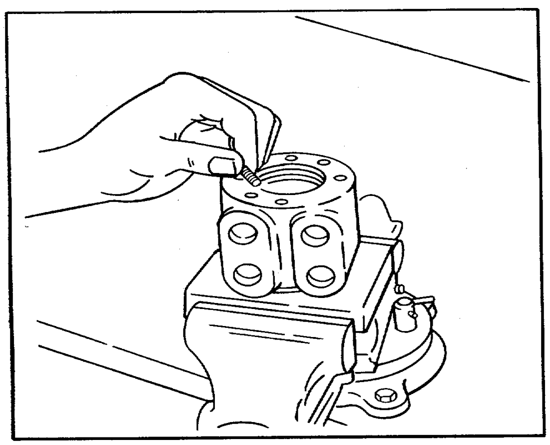


Figure 24.

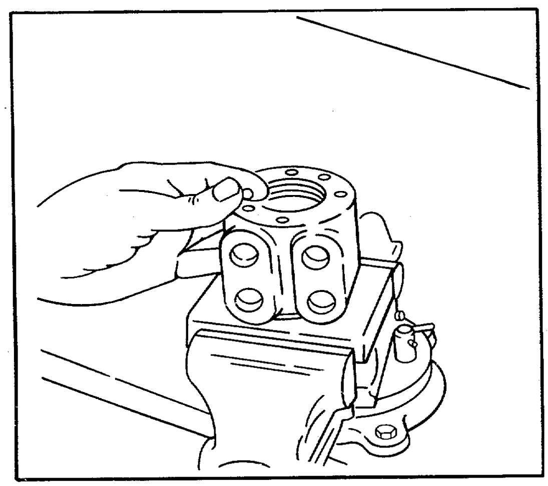


Figure 25.

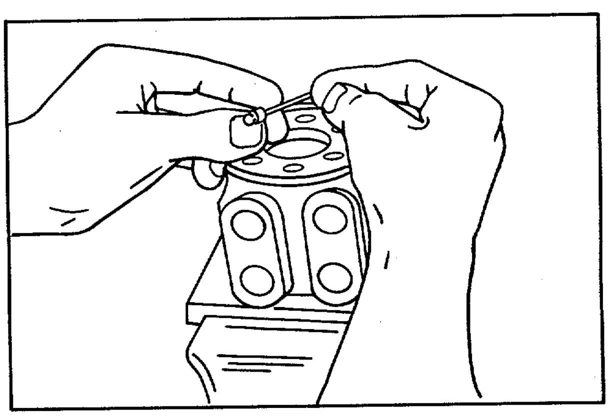
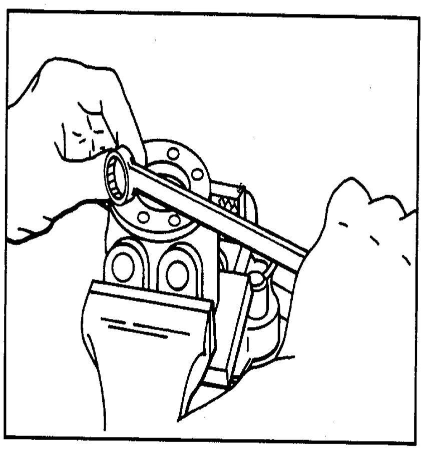


Figure 26.

Bring spring slots of both parts in line and stand parts on end of bench. Insert spring installation tool through spring slots of both parts. Tool is available as part no. 600057. Position 3 pairs of centering springs (or 2 sets of 3 each) on bench so that extended edge is down and arched center section is together. In this position, enter one end of entire spring set into spring installation tool (refer to Fig. 30).

Compress extended end of centering spring set and push into spool sleeve assembly withdrawing installation tool at the same time (refer to Fig. 31).



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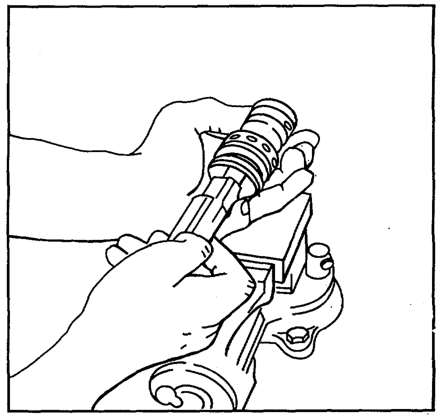

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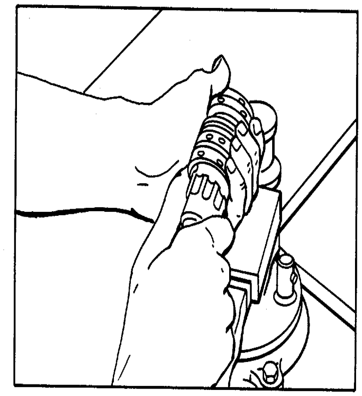

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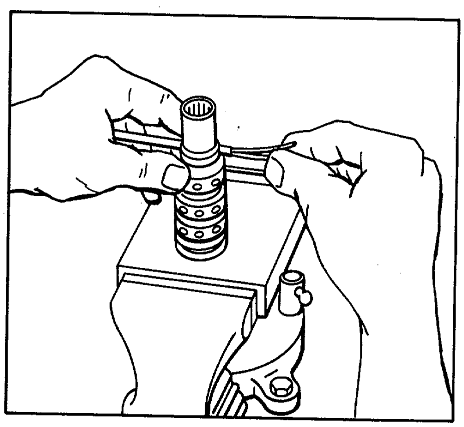


Figure 30.

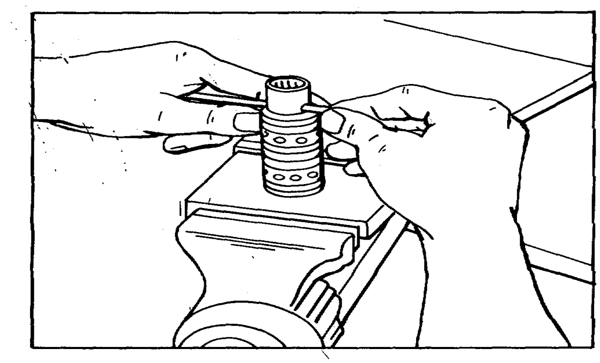


Figure 31.

STEERING CONTROL REASSEMBLY

Center the spring set in the parts so that they push down evenly and flush with the upper surface of the spool and sleeve (refer to Fig. 32).

Install cross pin through spool assembly (refer to Fig. 33).

Push into place until cross pin is flush or slightly below the sleeve diameter at both ends (refer to Fig. 34).

Position the housing on a solid surface with the port face down. Start the spool assembly so that the splined end of the spool enters the 14-hole end of the housing first (Refer to Fig. 35).

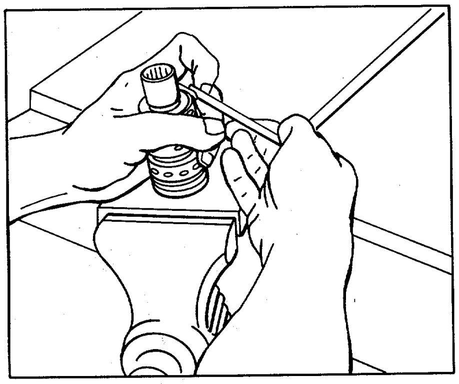


Figure 32

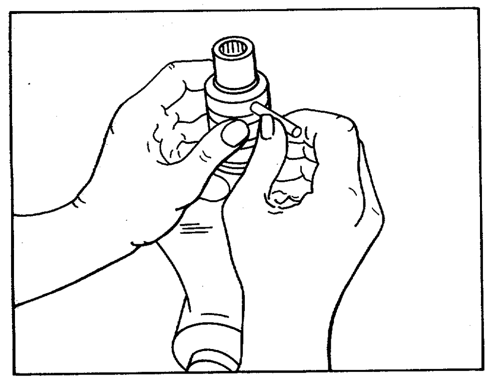


Figure 33

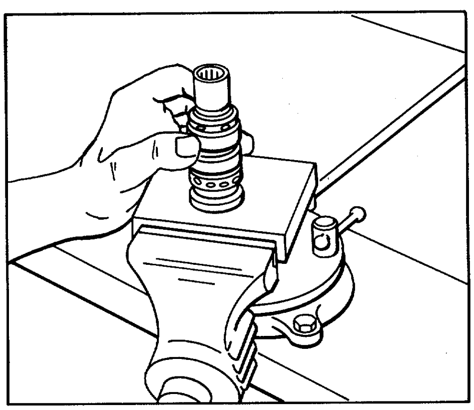


Figure 34

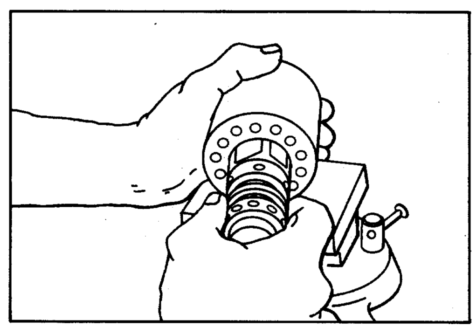


Figure 35

Be extremely careful that the parts do not cock out of position while entering. Push parts gently into place with slight rotating motion (refer to Fig. 36). Bring the spool assembly entirely within the housing bore until the parts are flush at the meter end or 14-hole end of the housing. Do not pull the spool assembly beyond this point to prevent the cross pin from dropping into the discharge groove of the housing. With the spool assembly in this flush position, check for free rotation within the housing by turning with light finger force at the splined end (refer to Fig. 37).

Hold the parts in this flush position and rest the 14-hole end of the assembly on the protective block on the vise throat and clamp lightly across the port face with the vise.

NOTE

It is good service policy to replace all seals when unit is reassembled. They are available in kit form part no. 5140.

Check the condition of the O-ring seal on the check plug and replace it if necessary. Install the check plug in the check hole with a steady pressure while rocking it slightly so that the O-ring feeds in smoothly without cutting (refer to Fig. 38 and 39).

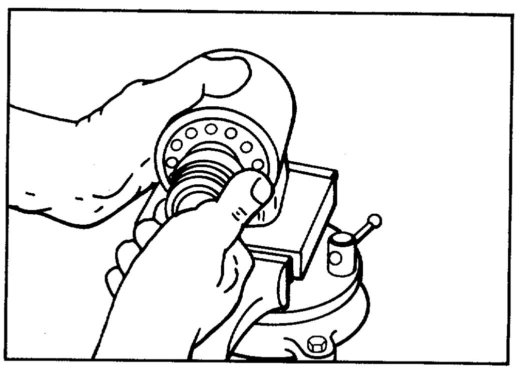


Figure 36.

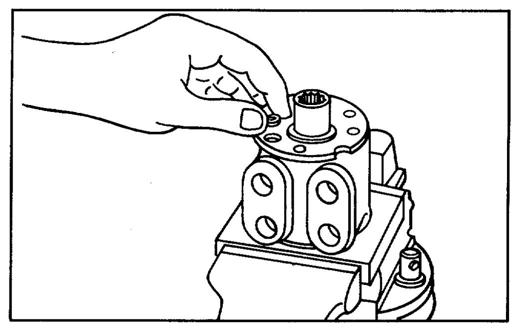


Figure 38.

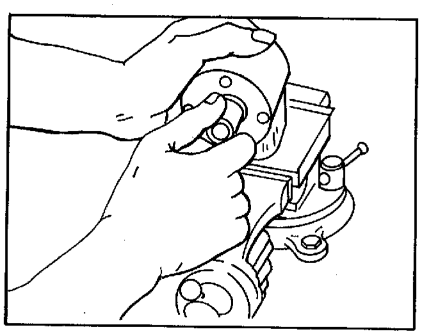


Figure 37.

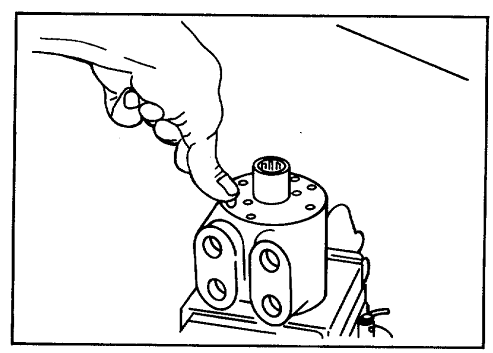


Figure 39.

Position the cap locator bushing with large O.D. chamfer UP partly into end of housing (refer to Fig. 40). Insure that it seats against spool assembly flat and smooth by rotating with fingertips.

Check the mounting plate and shaft seal carefully to insure that they are clean and in good condition. Insure that the mounting plate seal grooves are clean and smooth. Each of these seals is slightly larger than its seal groove so that they will be adequately retained in service. Push each gently into place and smooth down into seal groove with fingertip (refer to Fig. 41).

NOTE

Quad ring shaft seal may be used to replace O-ring shaft seal in early units and will function properly in original seal groove.

Thin oil seal at exterior of mounting plate is a dirt-exclusion seal and does not generally need replacement. If this is replaced it should be pressed into counterbore so that the lip is directed away from the unit.

Place the mounting plate subassembly over spool shaft and slide down into place over cap locator bushing smoothly so that seals will not be disrupted in assembly (refer to Fig. 42). Align boltholes with tapped holes. Be certain that the mounting plate rests fairly flush against end of housing assembly so that the cap locator bush- ing is not cocked and install four mounting plate capscrews. Tighten these evenly and gradually to 21 lb ft (28.5 Nm) torque. (Refer to Fig. 43.)

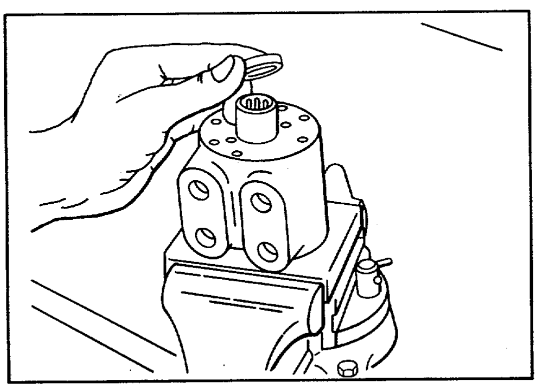
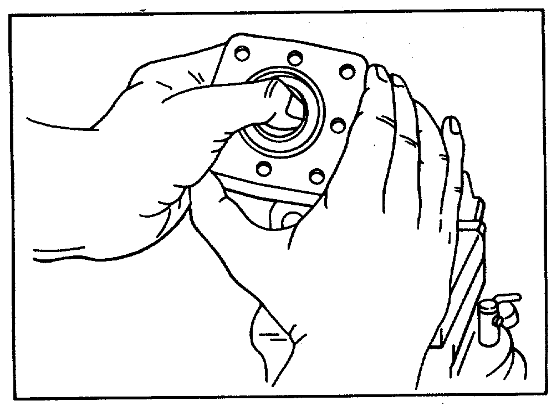


Figure 40.



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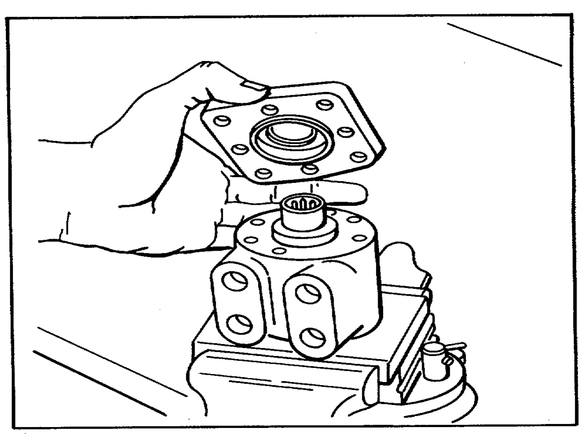


Figure 42.

Reposition in vise and clamp across the edges of the mounting plate. Check to insure that the spool and sleeve are flush or slightly below the 14 hole surface of the control housing (refer to Fig. 44).

Clean the upper surface of the housing by wiping with the back of a clean hand or the butt of the thumb. Clean each of the flat surfaces of the meter sec- tion parts as it is ready for assembly in a similar way (refer to Fig. 45).

Place the plate over this assembly so that the boltholes in the plate align with the tapped holes in the housing (refer to Fig. 46). Place the meter gear ring on the assembly so that the boltholes align (refer to Fig. 47).

Place the splined end of the drive within the meter-gear star so that the slot at the control end of the drive is in alignment with the valleys between the meter-gear teeth (refer to Fig. 48).

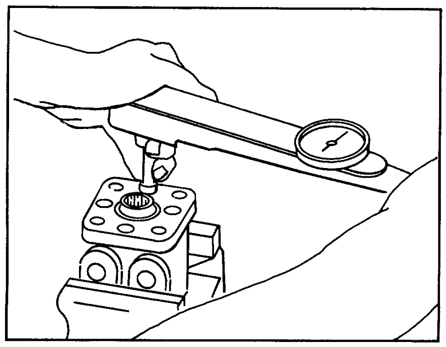
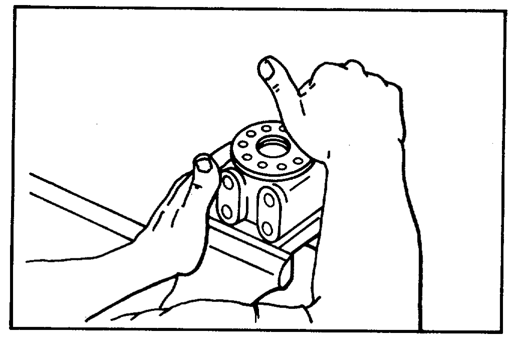


Figure 43.



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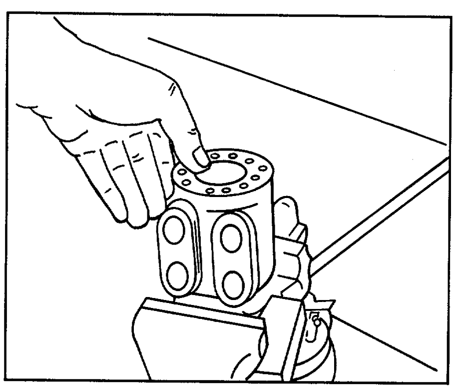


Figure 44.

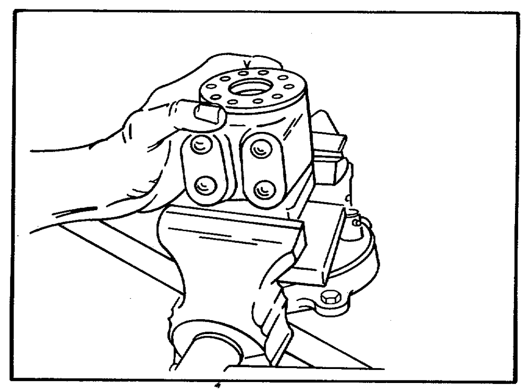


Figure 46.

Push the splined end of the drive through the gear so that the spline extends about one-half its length beyond the meter-gear star and hold it in this position while installing into the unit. Note the position or direction of the cross pin within the unit. Enter the meter-gear star into the meter-gear ring and wiggle the parts slowly in position so that the drive does not become disengaged from the meter-gear star. Hold the plate and meter-gear ring in position on the assembly while the star is being installed. Rotate the meter-gear star slightly to bring the cross slot of the drive into engagement with the cross pin and the splined end of the drive will drop down against the plate (refer to Fig. 49, 50, and 51).

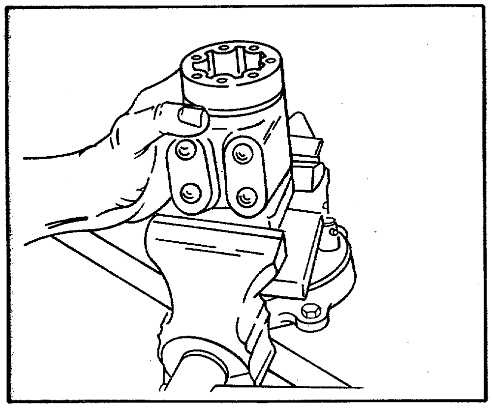


Figure 47.

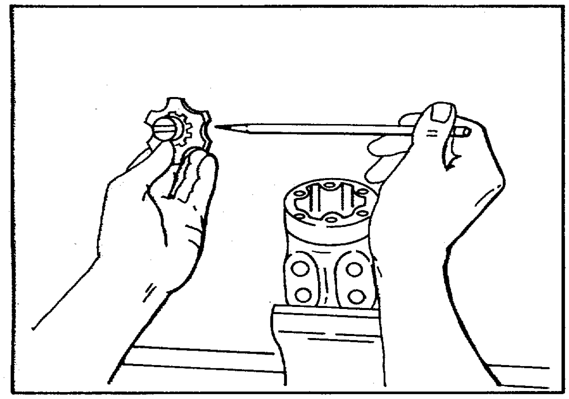


Figure 48.

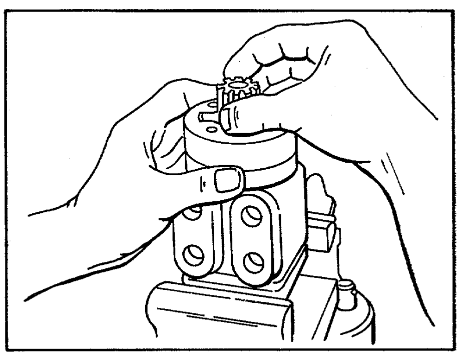


Figure 49.

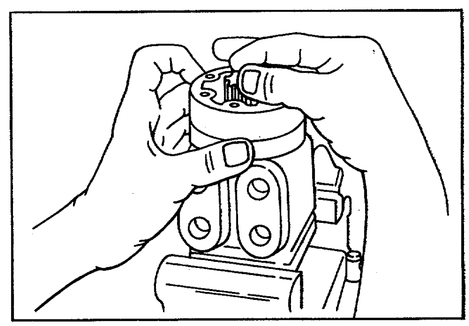


Figure 50

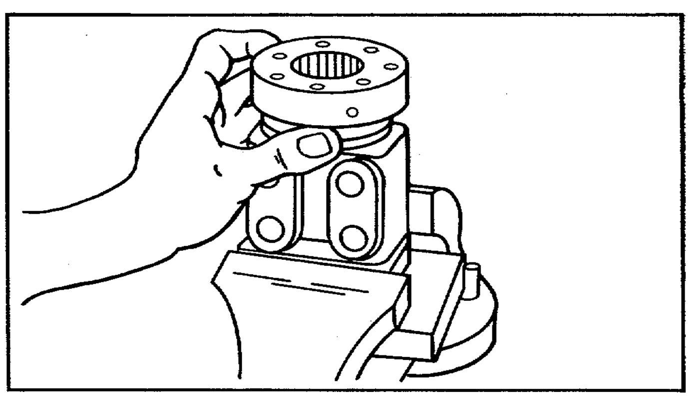


Figure 51.

CAUTION

Alignment of the cross slot in the drive with valleys between the teeth of the meter-gear star determines proper valve timing of the unit. There are 12 teeth on the spline and six pump teeth on the star. Alignment is exactly right in six positions and exactly wrong in six positions. If the parts slip out of position during this part of the as- sembly, repeat until you are certain that correct alignment is obtained (refer to Fig. 48).

Place the spacer in position within the end of the meter-gear star (refer to Fig. 52). (No spacer used on B size displacement units.) If the spacer does not drop flush with the gear surface, the drive has not properly en-gaged the cross pin-recheck. Place the meter end cap over the assembly and install two capscrews, finger-tight, to maintain alignment of the parts (refer to Fig. 53). Install all seven cap- screws and bring them gradually and evenly to 12.5 lb ft (16.94 Nm) torque. (Refer to Fig. 54.)

Check the condition of the column as- sembly, clean it, and replace on the unit with two capscrews oriented as before. Rotate the steering shaft while bringing the surfaces into con- tact to allow splines to engage (refer to Fig. 55). If in doubt, follow the orientation as shown. Tighten cap- screws to 23 lb ft (31 Nm) torque. (Refer to Fig. 56.)

The unit is now ready to be returned to service.

To service earlier units, follow a similar procedure. In units with a hat-shaped check plug, use gasket no. 20911 between the housing and the mounting plate. Insure that each part is smooth and clean by rubbing on 400- grit abrasive paper before cleaning for reassembly

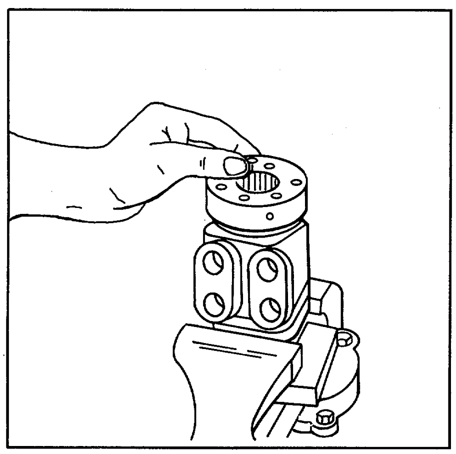


Figure 52.

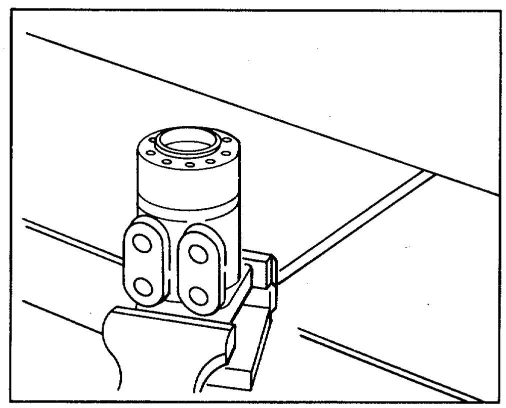


Figure 53.

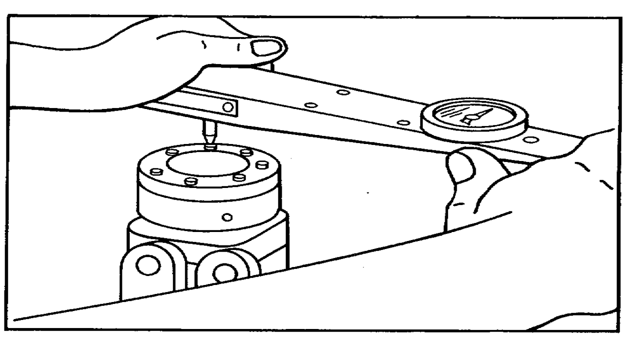


Figure 54

In units which have thin plastic gaskets at the meter section seams a gasket must be used at each side of the ring gear unless the entire gear set is replaced. Replacement gear sets are sized so that the gasket should not be used.

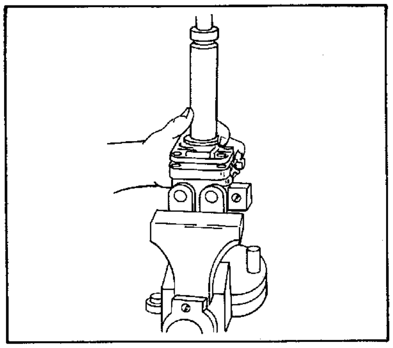


Figure 55.

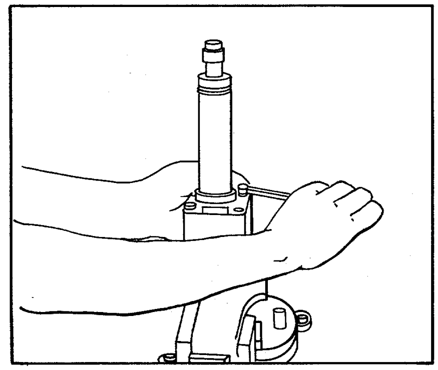


Figure 56.

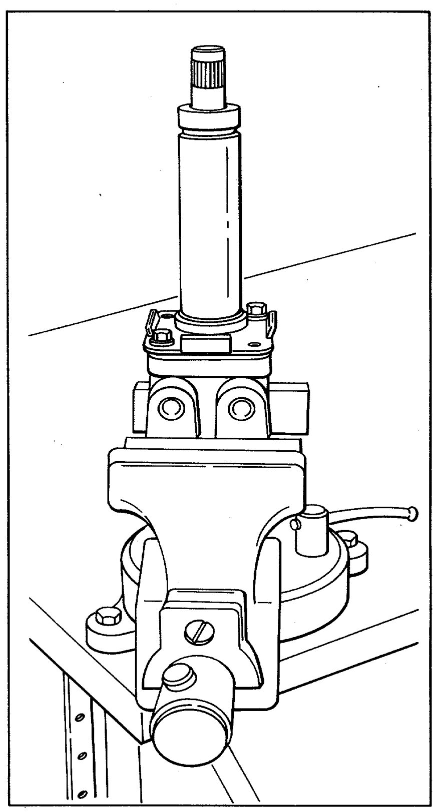


Figure 57.

BREAKSHOE REPLACEMENT

The hydraulic brake, commonly referred to as the plain H, is a light duty, two-shoe-type brake, mounted on a backing plate which also serves as a dust shield (refer to Fig. 1). Adjustable anchor pins provide a means of centering the brakeshoe arc in relation to the drum, and secondary or minor adjustments are made by rotating the eccentric cam which bears on the brakeshoe web or pin in the shoe web.

HYDRAULIC BRAKE LAYOUT

DISASSEMBLY (Refer to Fig. 2 and 3)

1. Disconnect brakeshoe return spring.
2. Remove anchor pin C-washers and guide pin locks and washers.
3. Remove brakeshoe and lining assemblies.
4. Remove anchor pin locknuts, lockwashers, and anchor pins.
5. For complete disassembly remove capscrews, washers, and wheel cylinder assembly and disconnect hydraulic lines.

REASSEMBLY (Refer to Fig. 2 and 3)

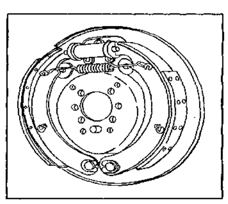
1. Position wheel cylinder, install capscrews, and lockwashers and tighten securely. Reconnect hydraulic lines.
2. Insert anchor pins and install washers and locknuts. (Punch marks must be together and wrench flats in line.)
3. Position shoe and lining assemblies and install washers and lockrings.
4. Back off adjusting cams and position shoes on push rods in wheel cylinder.
5. Hook shoe return spring in brake- shoe web holes.

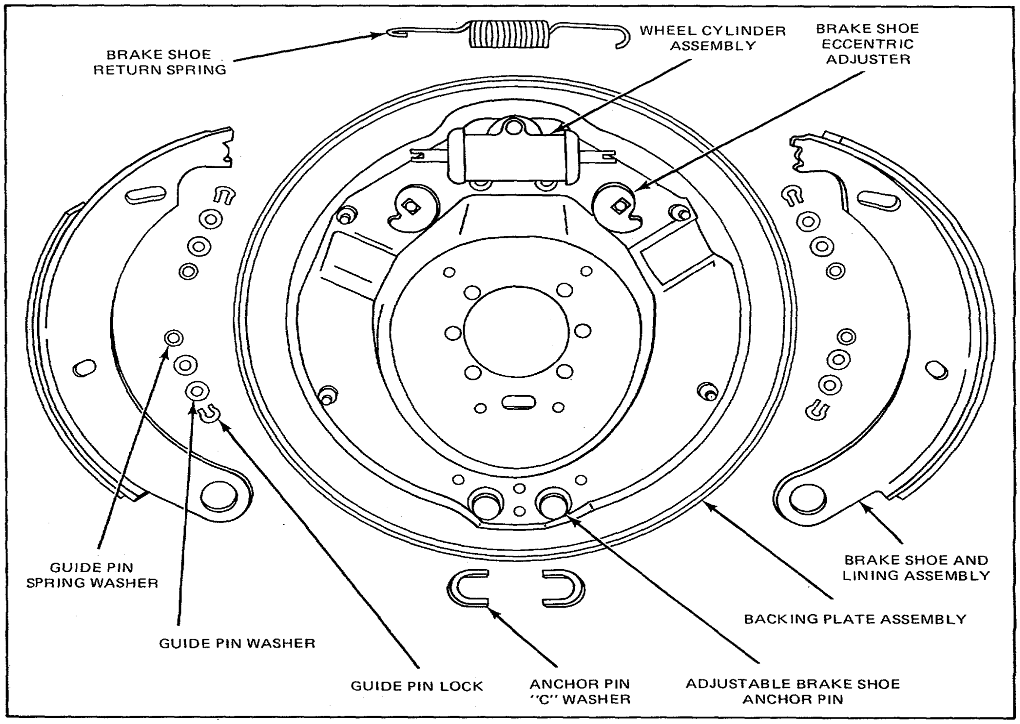
ADJUSTMENT

Following overhaul or when new linings are installed, the initial adjustment should be carefully made to both properly locate the curvature of the lining to the drum and obtain the proper clearance.

Each shoe must be adjusted to center the brakeshoe arc in relation to the drum. Adjust cam to bring lining into contact with the drum and rotate anchor pin sufficiently to relieve drag. Repeat until additional rotation of anchor pin will no longer relieve drag. Lock anchor pin locknut and back off cam sufficiently to permit wheel to turn freely (refer to Fig. 4 and 5).

Subsequent adjustments to compensate for lining wear are made with the eccentric cam only (refer to Fig. 4 and 5). Turn cam to bring lining into contact with the drum. Back off sufficiently to permit free rolling drum. Repeat on opposite shoe.





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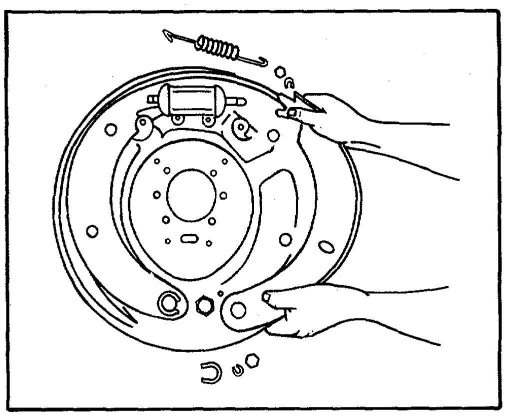


Figure 3.

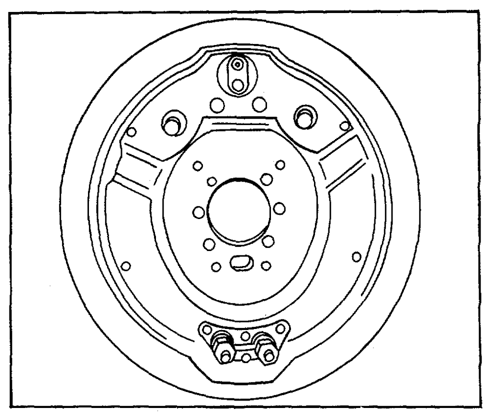


Figure 4.

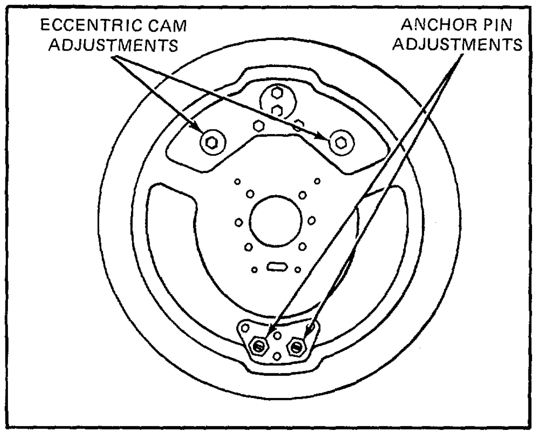


Figure 5.

LUG NUTS

WHEEL STUD NUT WRENCH TORQUES

Wheel lug nuts will loosen if not correctly torqued.

A torque wrench of proper capacity is recommended to torque lug nuts. Hand tightening is not adequate or consistent

In addition to the initial tightening it is important to recheck the nuts and retighten after the first trip.

If checking a new vehicle, nuts should be rechecked after the driveaway

Recommended wheel mounting torque

Highway Vehicles		
Budd Std. SCN Mtg.	11/16"-16	300-400
	¾"-16	450-500
Budd Std. DCN Mtg.	¾"-16	450-500
	1-1/8"-16	450-500
Off-The-Road Vehicles		
	¾"-16	450-500
Budd Std. DCN Mtg.	1-1/8"-16	450-500
	1-1/8"-16	650-750*
Budd Heavy Duty	15/16"-12	750-900
DCN Mtg.	1-5/16"-12	750-900
Backnut		
	¾"-16	175-200
(Inner End of Wheel Stud)	7/8"-15	175-250
	1"-14	175-300

SCN = Single Cap Nut Mounting
DCN = Double Cap Nut Mounting
back nuts or headed studs.

*When using shoulder studs
with 7/8" and 1" thread

CHECKS

This simplified guide to many miles of troublefree service points out what to look for and what to do about things that happen to wheels in light or heavy duty, in highway or off-the-road operation. The wheels and parts shown are typical. See the Budd Catalog for the complete line.

The inspection schedules and routines suggested can be modified to suit individual fleet requirements. Mileage increments and time periods have not been established, since many factors govern the frequency of service required to maintain wheels.

The most important thing to remember is that most wheel problems are caused by just two factors-overloading and improper maintenance.

And when loads are matched to the proper wheel, simple checks are all that are required for long, trouble-free operation.

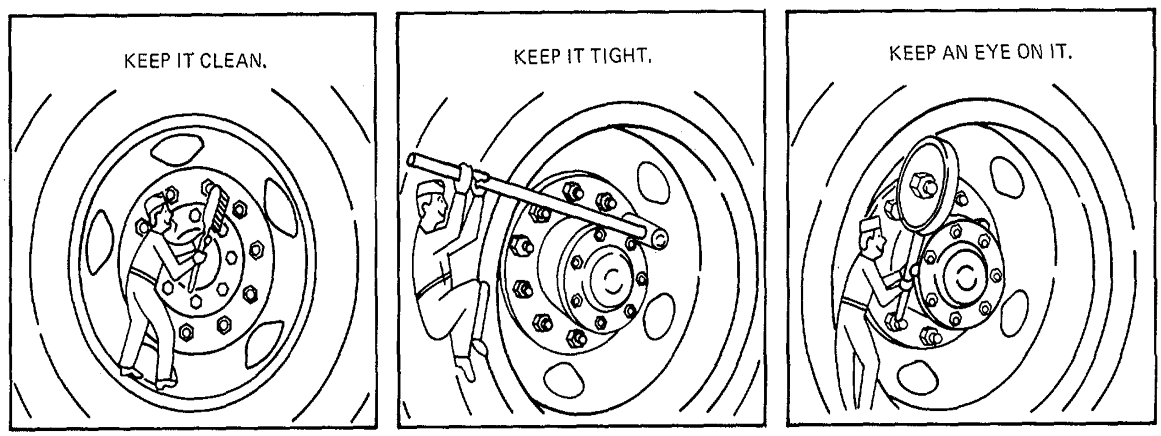


Figure 1.

RECOMMENDED PROCEDURE FOR REPLACING STUDS

When a broken stud is replaced, the stud on each side of it should also be replaced. If more than one stud is broken, replace all studs.

Use the correct stud.

If the correct length stud is not used, the back nut (jamnut) may not seat firmly against the drum.

Too much standout from the mounting face of the hub may make it impossible to secure the inner wheel against the hub face.

In replacing studs, remember that right-hand studs go on the right-hand side of the vehicle and left-hand studs on the left-hand side when facing forward.

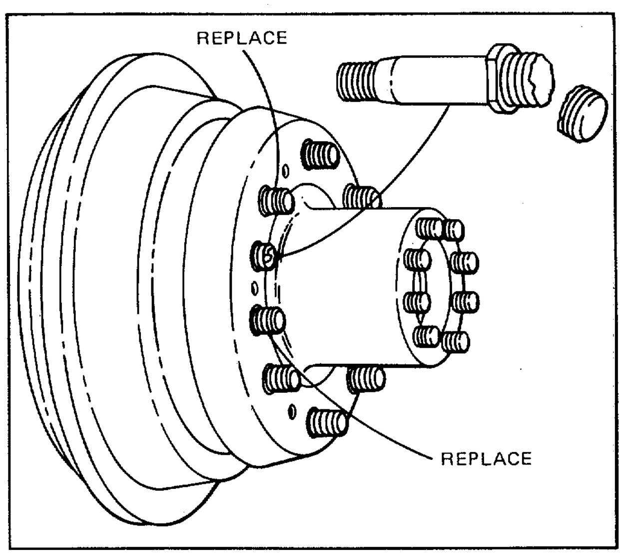


Figure 2.

PROPER TIGHTENING OF CAP NUTS IS OF UTIMOST IMPORTANCE FOR TROUBLE-FREE PERFORMANCE

Keep it tight

The mounting, being essentially a friction/compression assembly, depends upon the forces applied by the cap nuts for its efficiency. Proper initial torquing will prevent broken studs, cracks at the stud holes, or damaged ball seats.

Air wrench

The tool is used extensively because of its utility and speed. However, over- tightening or insufficient torque can cause problems.

Insufficient torque can cause stud breakage and damaged ball seats. Overtightening can overstress studs and damage threads.

It is imperative to check wrench torque output at regular intervals. This should be done with a torque wrench.

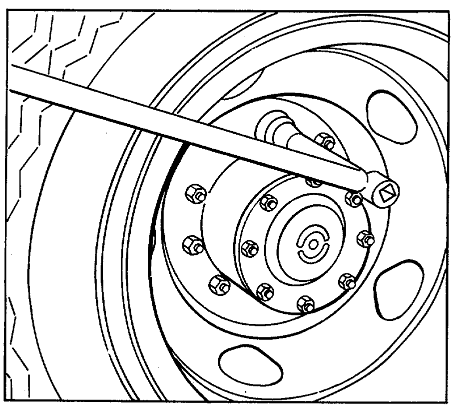


Figure 3.

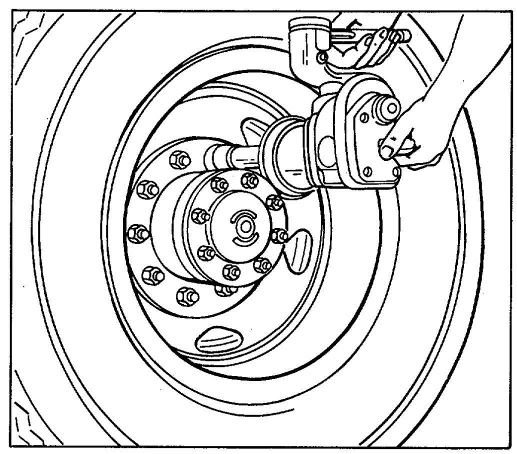


Figure 4.

TIGHTENING PROCEDURE LUG NUTS

TOOLS TO USE IN TIGHTENING CAP NUTS

A bar wrench

You can easily arrive at the proper torque with this simple tool. Since pound/feet of torque is weight applied x distance in feet, the following example will help you determine applied torque:

A 180-lb mechanic, applying his full weight 3 feet out on the bar until the cap nut will no longer turn, will exert 540 lb ft of torque.

The torque wrench

This precision device has a readout gauge which indicates applied torque. It is essential in obtaining 100% torque accuracy.

To check a bar wrench or an air wrench, you only have to apply the torque wrench on a previously tightened nut and read the torque indicated on the gauge.

The only accurate way to verify torque is to check in the direction of tightening the nut and note the reading at the point where the nut starts to turn.

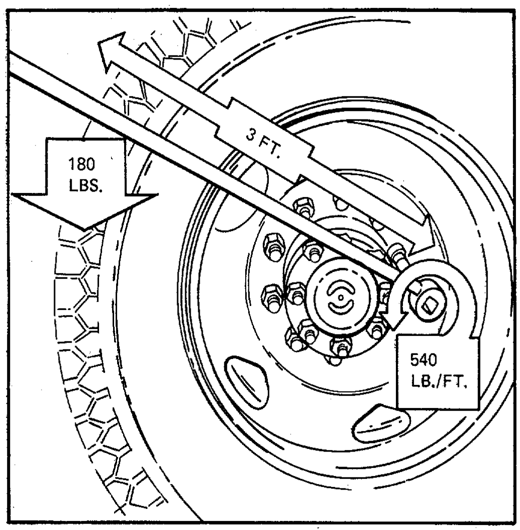


Figure 5.

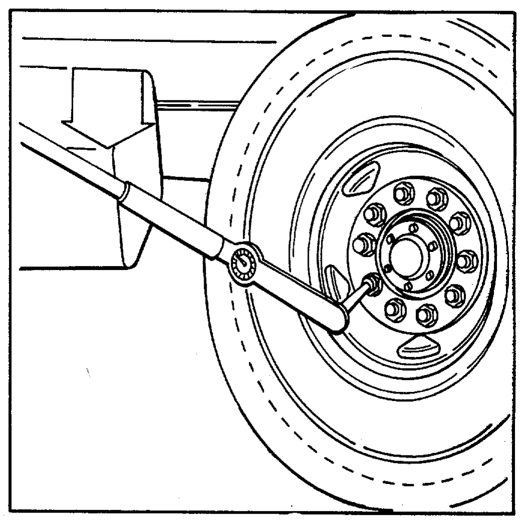


Figure 6.

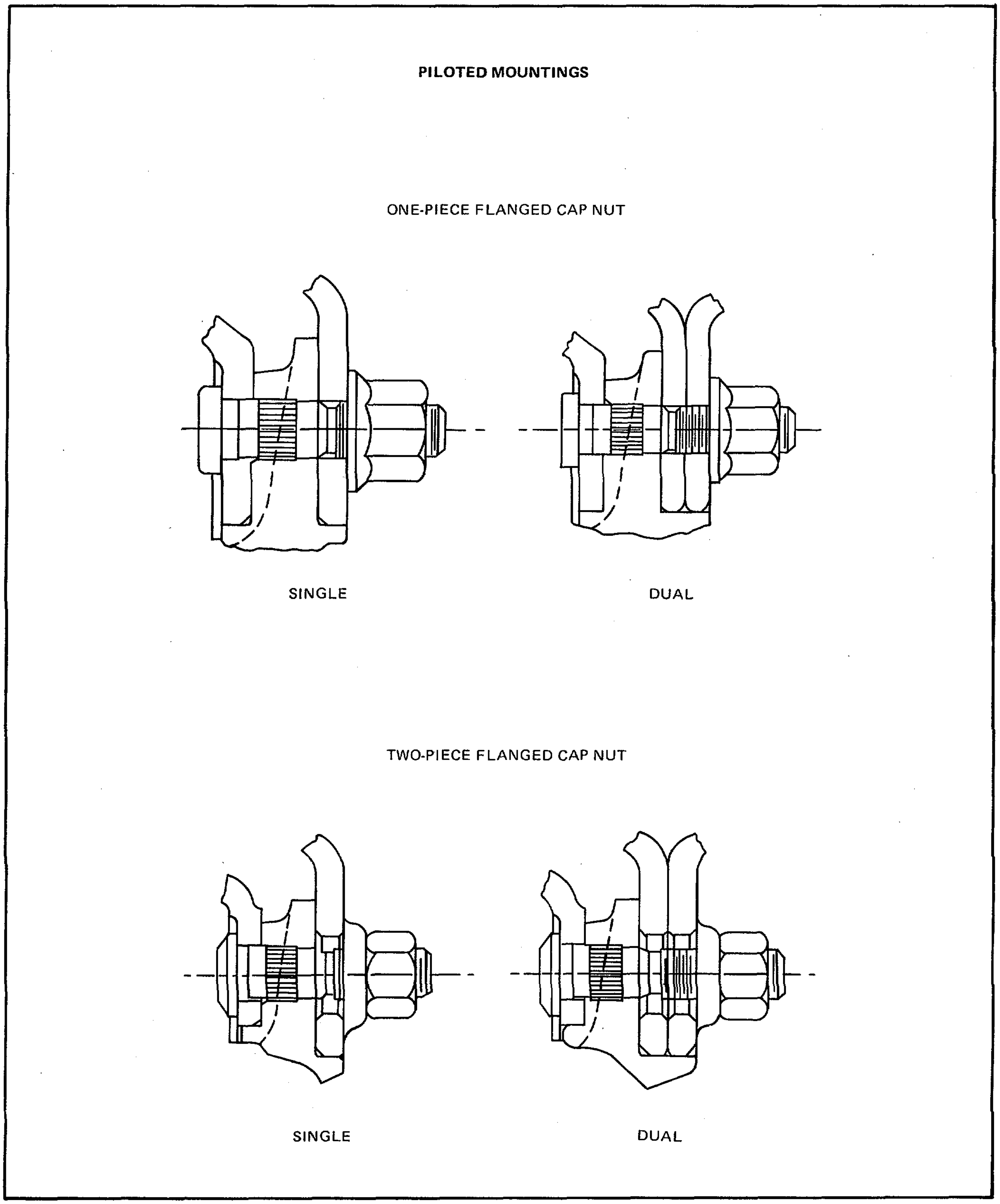

PILOTED MOUNTINGS
ONE-PIECE FLANGED CAP NUT
SINGLE
DUAL
TWO-PIECE FLANGED CAP NUT
SINGLE
DUAL

Figure 7.

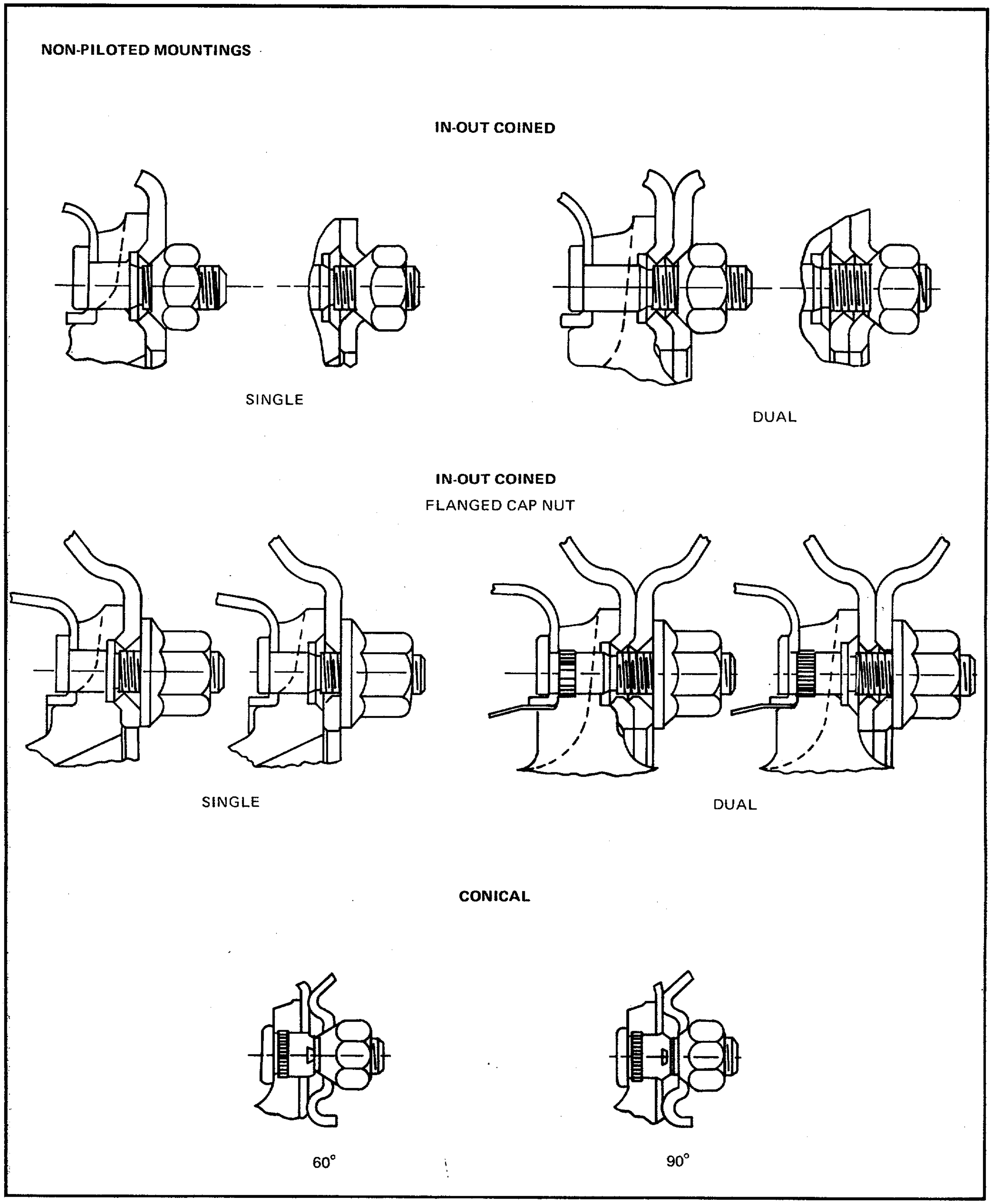

NON-PILOTED MOUNTINGS
IN-OUT COINED
SINGLE
DUAL
IN-OUT COINED
FLANGED CAP NUT
SINGLE
DUAL
CONICAL
60°
90°

Figure 8.

PLANETARY AXLES

CARE AND MAINTENANCE

Planetary axles incorporate a single reduction carrier with bevel or hypoid gearing mounted in the axle center. The second reduction is of planetary design spur gearing built into the wheel hubs.

Planetary axles permit the bevel or hypoid gearing of the carrier and the axle shafts to carry only a nominal torsional load while at the same time providing the highest practical numerical gear reduction at the wheels.

The hypoid pinion and differential as- sembly of the first reduction are sup- ported by tapered roller bearings. The pinion-bearing preload is adjusted and maintained by a hardened precision spacer between the inner and outer bearings. The differential tapered bearing preload is adjusted and maintained by the positioning of the threaded adjusting rings in the carrier leg and cap bores.

The spur teeth of the sun gear (which floats) mesh with teeth of the planet spur gears. The planet spur gears ro- tate on planet pins which are mounted in a spider. The planet spur gear teeth inturn mesh with teeth of the floating ring gear.

Power is transmitted by the pinion and gear of the first reduction to the axle shafts empowering the sun gear of the second reduction, through the revolving planet gears, and into the planetary spider which drives the wheel hub.

The servicing of the single reduction carrier assembly used in the planetary housing center is thoroughly covered in our Field Maintenance Manual No. 5 (or 5A if drive unit is the through-drive type).

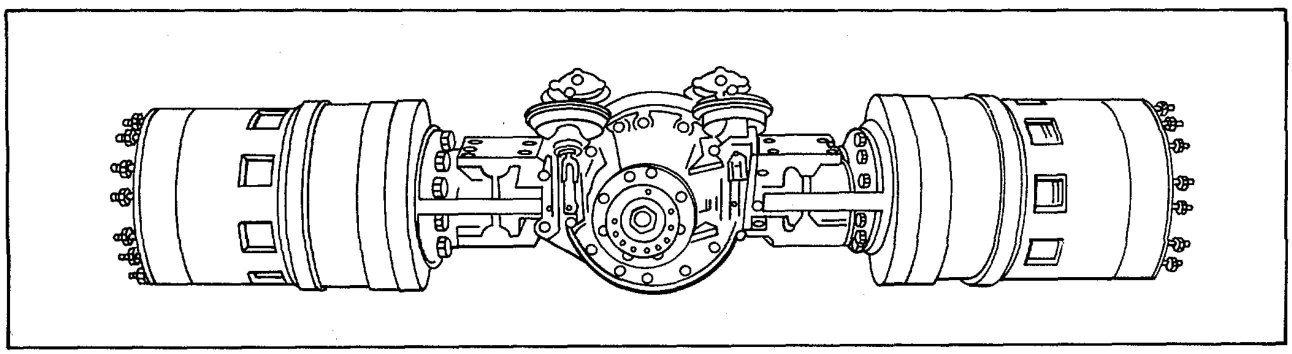


Figure 1. Planetary Rigid Types (PR)

DISASSEMBLY OF PLANETARY OUTER ENDS

Before starting the disassembly of either the planetary steering-type or planetary rigid-type axles, the following procedure and precautions should be taken:

1. Jack up both ends of axle so that tires clear the ground. Due to the extreme weight of vehicles under which planetary-type axles are used, the axle should then be blocked up under each spring seat to safely support the weight and hold axle at this level. The jacks may then be removed to provide adequate working space with no danger of axle end falling or shifting.

2. Remove the wheel nuts or rim lug nuts where employed.

3. Remove the tire and wheel or tire and rim where employed.

4. Rotate hub assembly so that the drainplug is at the bottom.

5. Remove the plug and drain lubricant.

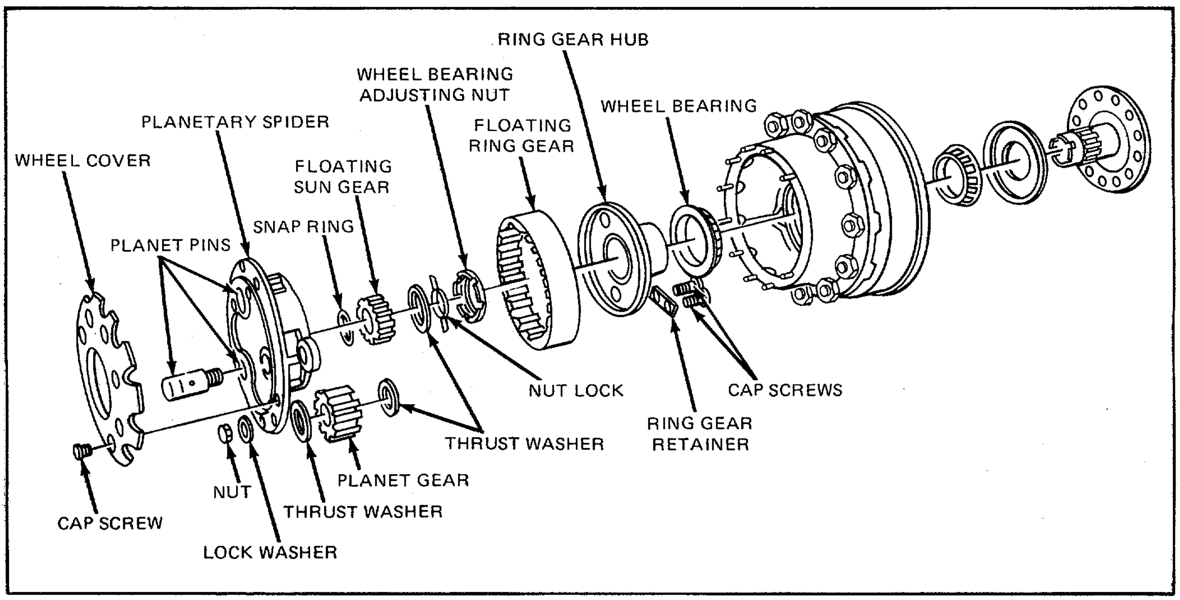


Figure 2. Exploded View Illustrating the Conventional Arrangement of Component Parts Used in Rigid Model Planetary Wheel Outer Ends

DISASSEMBLE THE PLANETARY ASSEMBLY

1. Remove the planetary wheel cover capscrews (refer to Fig. 3).

2. Remove the planetary wheel cover.

3. Remove the cover to planetary spider gasket (refer to Fig. 4).

4. Remove the planetary spider stud nuts and lockwashers.

5. Separate and remove planetary spider assembly from wheel hub assembly by use of puller screws in threaded holes provided in the spider flange (refer to Fig. 5).

6. Remove planetary spider to hub gasket.

DISASSEMBLE PLANETARY SPIDER ASSEMBLY

Planetary spur gears rotate on planet pins. Each gear rotates between hardened thrust washers.

1. Press out the planet gear pins as shown (refer to Fig. 6).

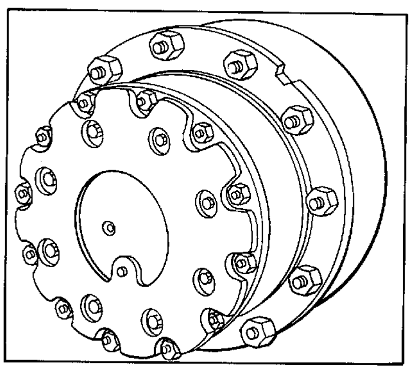


Figure 3.

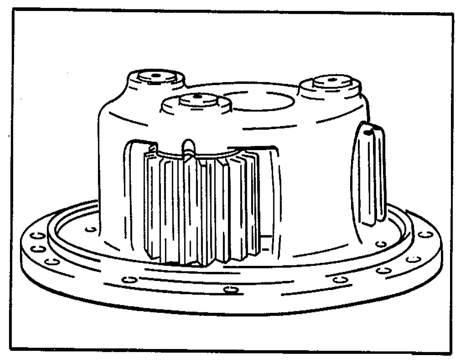


Figure 5.

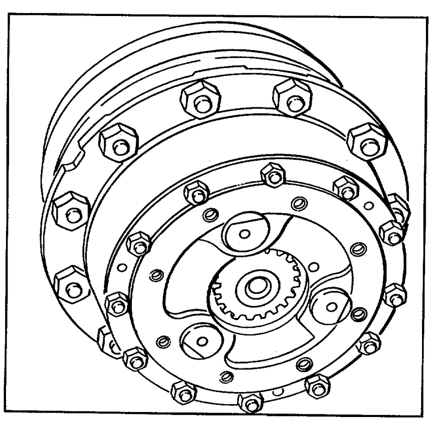


Figure 4.

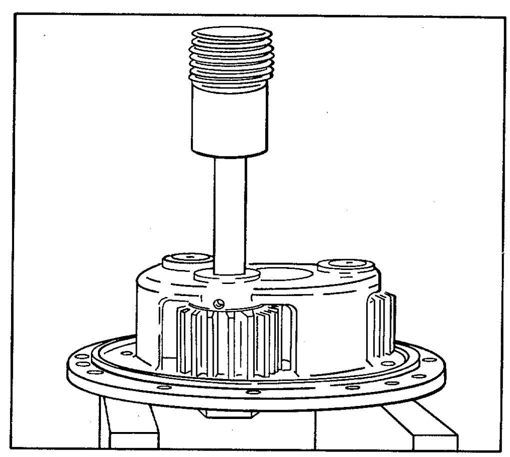


Figure 6.

2. Remove the planet gears and their respective thrust washers (refer to Fig. 7).

NOTE

Thrust washers are designed for opposite sides of planet pinions and can only be installed in their correct locations.

REMOVE THE FLOATING RING GEAR ASSEMBLY

1. Remove the lockring from end of axle shaft (refer to Fig. 8).

2. Remove the axle shaft sun gear (refer to Fig. 9).

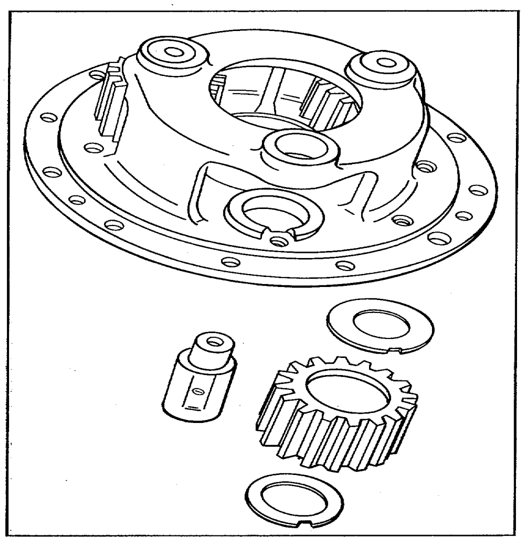


Figure 7.

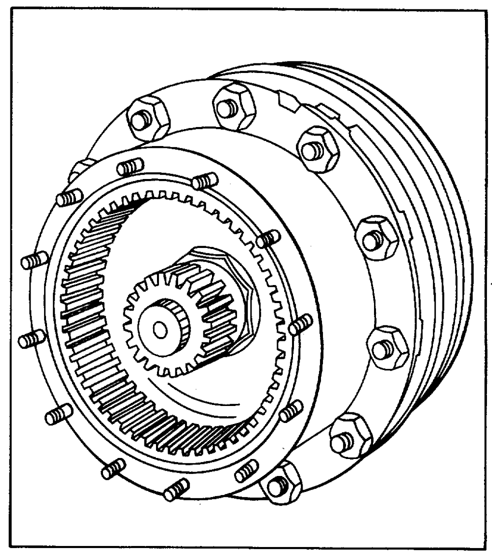


Figure 8.

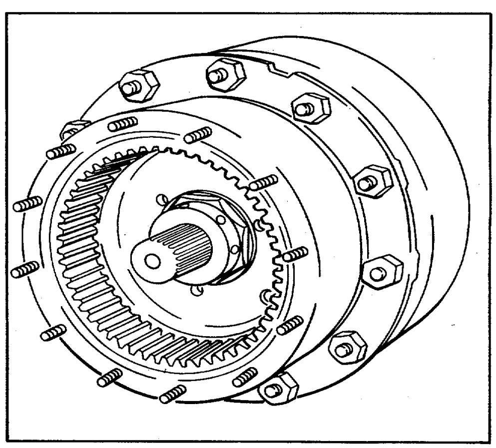


Figure 9

NOTE

On some of the larger PR models the axle shaft and sun gear are integral. On these models remove the complete axle shaft, exercising care not to damage the oil seal. The sun gear thrust washer may then be removed from the axle shaft.

3. Remove the sun gear thrust washer (refer to Fig. 9).

4. Remove the axle shaft on rigid models that do not employ the integral sun gear.

5. Remove the wheel bearing adjusting nut lock. (Wheel bearing adjusting nuts are all of the single nut construction and may be locked to the hub spindle in different methods depending on model.)

6. Remove the wheel bearing adjusting nut (refer to Fig. 9).

7. Remove the floating ring gear assembly. Puller screw holes are provided in the ring gear hub flange to start gear (refer to Fig. 10).

a. The floating ring gear is splined to the ring gear hub and secured by four evenly spaced plates, each plate being attached by two capscrews which are lockwired together (refer to Fig. 11).

b. The outer wheel bearing is mounted on the ring gear hub.

8. Separate the ring gear and ring gear hub by removing lock wire, cap- screws, and plates (refer to Fig. 11).

9. Remove outer wheel bearing from ring gear hub (refer to Fig. 11).

10. The ring gear hub assembly is made up of the hub and a hardened ring sleeve insert which is pressed into the hub from the outer side.

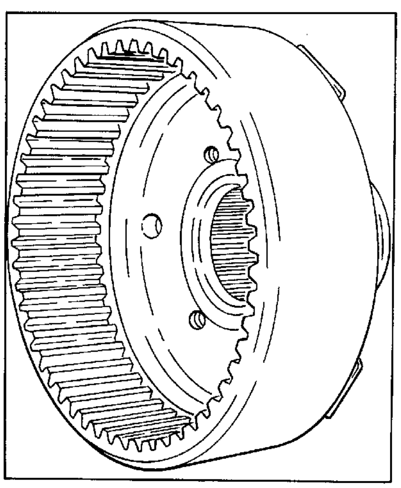


Figure 10.

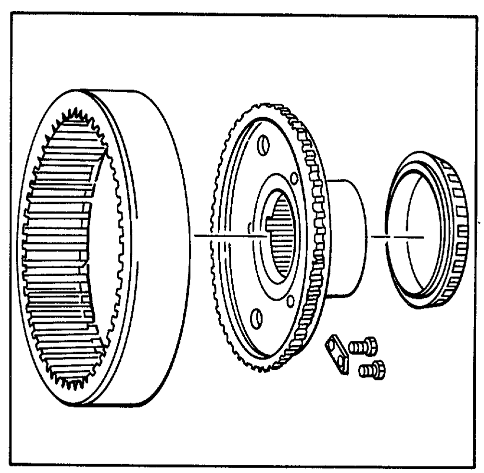


Figure 11

REMOVE THE WHEEL HUB AND DRUM ASSEMBLY

1. Lift the hub and drum slightly to relieve the hub weight and drum to brakeshoe drag and remove the assembly from the hub spindle (refer to Fig. 12)

2. If wheel bearings are to be re- placed, remove wheel bearing cups with a suitable puller.

DISASSEMBLE BRAKESHOE AND LINER ASSEMBLY

On planetary axles equipped with hydraulic brakes, the complete disassembly of the brakes is not necessary for the removal of the hub spindle. Adequate working clearance is provided by only removing the brakeshoe return spring (refer to Fig. 13).

1. If the brakeshoe and liner assemblies are to be removed for service or inspection, unhook and remove the brakeshoe return spring (refer to Fig. 13).

2. Remove anchor pin plate cotter key, stud nut, and plate (refer to Fig. 14).

3. Remove the brakeshoe and liner assemblies. For complete disassembly, remove push rods and brake cylinder.

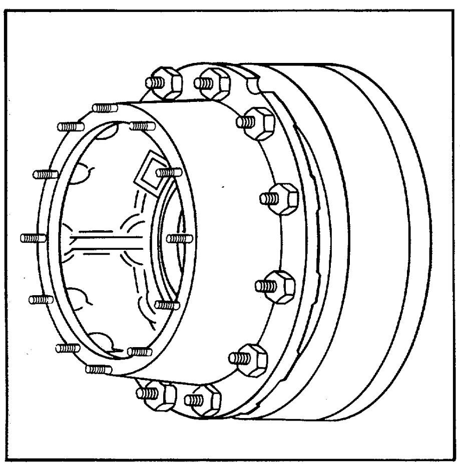


Figure 12.

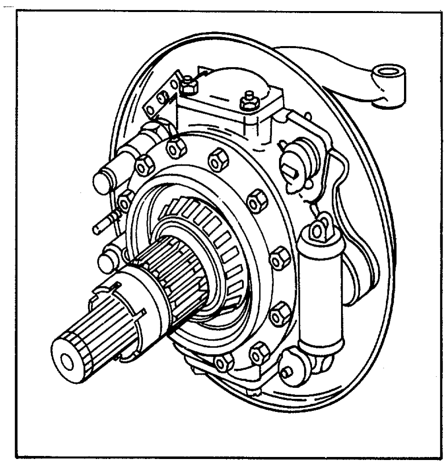


Figure 13.

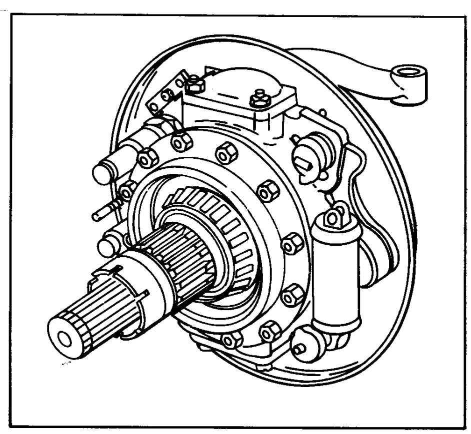


Figure 14.

4. If the brakeshoe and liner as- sembly are to be removed for service or inspection, unhook and remove the brakeshoe return spring (refer to Fig. 13).

5. Remove the anchor pin locks, felts, and felt retainers.

6. Remove the brakeshoe and liner assemblies.

7. For complete disassembly, remove the chambers, slack adjusters, and camshafts.

ON PR models, the oil seal and retainer assembly is located in the hub against the hub rear bearing cup and wipes the hub spindle. Remove the retainer and seal assembly from hub with a suitable puller. Remove bearing.

NOTE

Do not remove the oil seal from the retainer on PR models unless replacement is necessary.

Remove the bolts, nuts, and lockwashers on PR models.

Remove the hub spindle. Due care must be exercised not to damage the O-ring seal in the recess of housing mating- end of spindle on PR models (refer to Fig. 15).

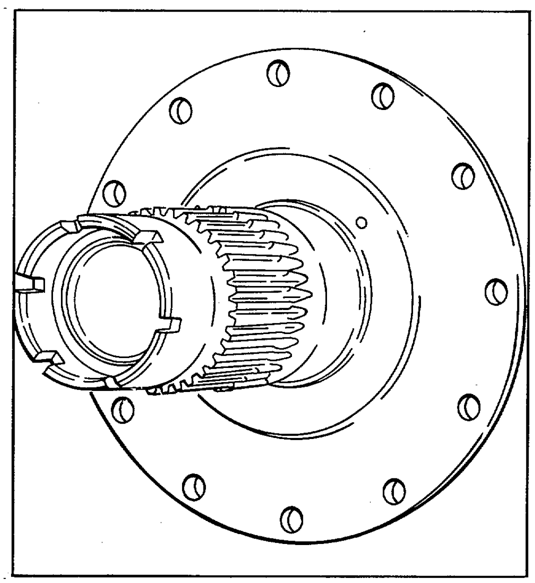


Figure 15.

PREPARE FOR REASSEMBLY

CLEAN, INSPECT, AND REPAIR

Parts having ground and polished surfaces such as gears, bearings, shafts, and collars should be cleaned in a suitable solvent such as kerosene or diesel fuel oil.

NOTE

Gasoline should be avoided.

DO NOT clean these parts in a hot solution tank or with water and alkaline solutions such as sodium hydroxide, orthosilicates, or phosphates.

We do not recommend steam cleaning assembled drive units after they have been removed from the housing. When this method of cleaning is used, water is trapped in the cored passage of the castings and in the close clearances between parts as well as on the parts. This can lead to corrosion (rust) of critical parts of the assembly and the possibility of circulating rust particles in the lubricant. Premature failure of bearings, gears, and other parts can be caused by this practice. Assembled drive units cannot be properly cleaned by steam cleaning, dipping, or slushing. Complete drive unit dis- assembly is a necessary requisite to thorough cleaning.

Rough Parts

Rough parts such as differential carrier castings, cast brackets, and some brake parts may be cleaned in hot solution tanks with mild alkali solutions, providing these parts are not ground or polished. The parts should remain in the tank long enough to be thoroughly cleaned and heated through. This will aid the evaporation of the rinse water. The parts should be thoroughly rinsed after cleaning to remove all traces of alkali.

WARNING

Exercise care to avoid skin rashes and inhalation of vapors when using alkali cleaners.

Complete Assemblies

Completely assembled axles may be steam cleaned on the outside only to facilitate initial removal and disassembly, providing all openings are closed. Breathers, vented shift units, and all other openings should be tightly covered or closed to prevent the possibility of water entering the assembly.

Drying

Parts should be thoroughly dried immediately after cleaning. Use soft, clean, lintless, absorbent paper towels or wiping rags free of abrasive material, such as lapping compound, metal filings, or contaminated oil. Bearings should never be dried by spinning with compressed air.

Corrosion Prevention

Parts that have been cleaned, dried, inspected and are to be immediately reassembled should be coated with light oil to prevent corrosion. If these parts are to be stored for any length of time, they should be treated with a good rust preventive and wrapped in special paper or other material de- signed to prevent corrosion.

INSPECT

It is impossible to overstress the importance of careful and thorough inspection of drive unit parts prior to reassembly

Thorough visual inspection for indications of wear or stress, and the replacement of such parts as are necessary will eliminate costly and avoidable drive unit failure.

1. Inspect all bearings, cups, and cones, including those not removed from parts of the drive unit, and replace if rollers or cups are worn, pitted, or damaged in any way. Remove parts needing replacement with a suitable puller or in a press with sleeves. Avoid the use of drifts and hammers. They may easily mutilate or distort component parts.

2. Inspect the planetary reduction, planet gears, sun gear, and ring gear assembly for wear or damage. Gears which are scored, pitted, ridged, or worn should be replaced.

3. Inspect planetary reduction for the following:

   a. Pitted, scored, or worn thrust washers.

   b. Worn or ridged planet pinion pins.

   c. Worn, scored, or chipped planet pinions.

4. Inspect axle shafts for signs of torsional fractures or other indications of impending failure.

REPAIR

1. Replace all worn or damaged parts. Replace all hex nuts with rounded corners, lockwashers, distorted snaprings, oil seals, gaskets, and socket felts at time of overhaul.

2. Remove nicks, mars, and burrs from machined or ground surfaces. Threads must be clean and free to obtain accurate adjustment and correct torque. A fine mill file or India stone is suitable for this purpose. Studs must be tight prior to reassembling the parts.

3. Tighten all the nuts and cap- screws to the correct torque. (Refer to Tabulation of Torque Limits following servicing instructions.)

4. The burrs caused by lockwashers at the spot face of stud holes of knuckle flanges, spider flange, or hub cover, should be removed to assure easy reassembly of these parts.

REASSEMBLE PIANETARY OUTER END

INSTALL OIL SEAL IN CARRIER HOUSING

1. Install oil seal in carrier housing at the connecting flange end with a suitable driver. Care must be exercised to locate the seal squarely against the seal recessed shoulder.

2. On units incorporating the axle shaft guide plate, start the plate into the end bore evenly with a hammer. Once plate is started square, drive the plate into position with a suitable driver.

CAUTION

DO NOT strike these hardened steel pieces directly with a steel hammer.

3. The inner axle shaft oil seals on some planetary models are located in the short bell housing at the connect- ing flange end. These models employ no axle shaft guide plates and must be installed in the seal bore squarely by use of a proper driver.

4. On most of the rigid models the spindle and brake spider assembly end is connected to the housing flange by bolts, lockwashers, and nuts after the oil seal has been properly installed.

INSTALL HUB SPINDLE ASSEMBLY

1. Install the inner wheel bearing on the hub spindle.

2. Position the hub spindle and wheel bearing assembly over the knuckle flange studs.

3. Place the oil seal and retainer assembly (refer to Fig. 2) over the studs and install the stud nuts.

Older models use oil seal and retainer assembly which is held in place against the spindle by means of a dowel.

4. Tighten nuts to correct torque.

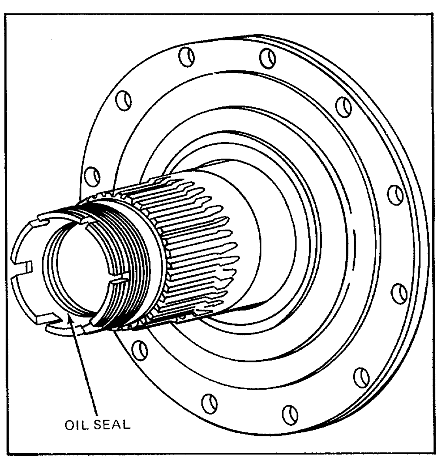


Figure 1.

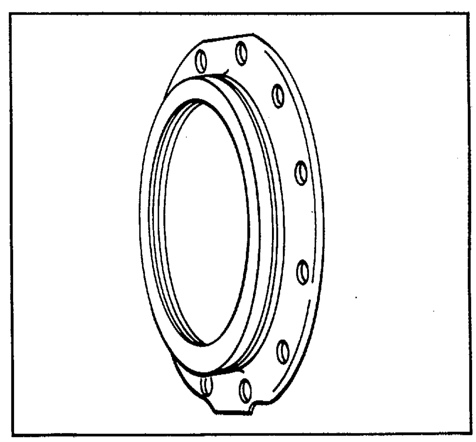


Figure 2.

On PR models, join spindle to connecting flange with bolts, lockwashers and nuts. Tighten nuts to correct torque.

INSTALL BRAKE ASSEMBLIES

Hydraulic (Refer to Fig. 4.)

1. Install brake cylinder and push rods.

2. Install brakeshoe and liner assemblies over anchor pins.

3. Install anchor pin plate, nut, and cotter key.

4. Align push rods with shoe webs and hook brakeshoe return spring.

5. For further detailed information, consult the hydraulic brake section in Field Maintenance manual No. 4.

ASSEMBLE FLOATING RING GEAR ASSEMBLY

1. Install splined ring gear hub into the ring gear splines flush with shoulder.

2. Install the hub to gear connect- ing plates and capscrews.

3. Tighten capscrews to correct torque.

4. Lock wire capscrews in sets of two.

5. Install the outer wheel bearing on ring gear hub journal squarely against hub shoulder. The inner race of bearing is a slide fit over the spindle hub journal.

ASSEMBLE HUB AND DRUM ASSEMBLY AND INSTALL

If hub bearing cups have been removed for replacement, install new cups with a suitable driving sleeve.

1. Lift the hub and drum assembly onto the hub spindle and position so that the inner Cup rests on the inner bearing rolls.

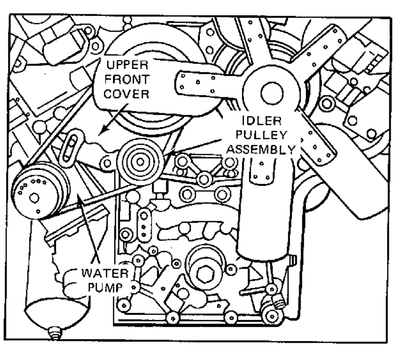


Figure 3.

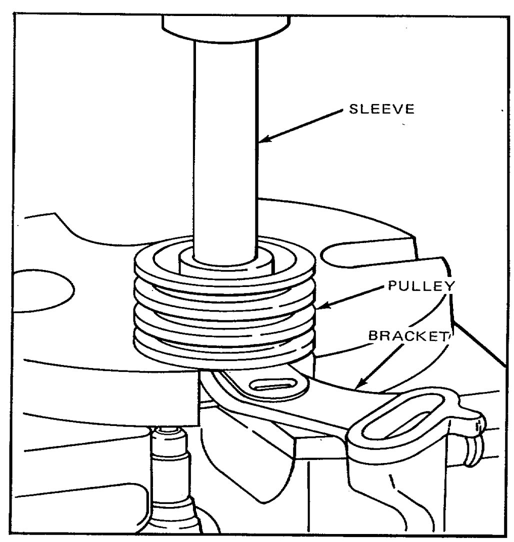


Figure 4.

2. Install the floating ring gear assembly, while at the same time lifting the weight of the hub and drum assembly to allow the outer bearing to mate with outer hub bearing cup.

3. Install the wheel bearing adjusting nut.

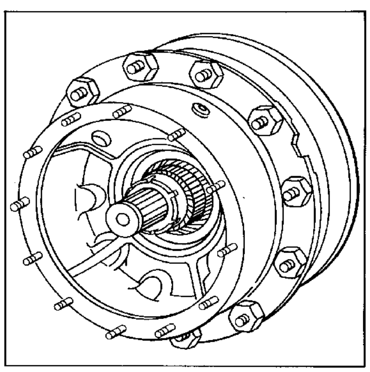
WHEEL BEARING AWJUSTMENT

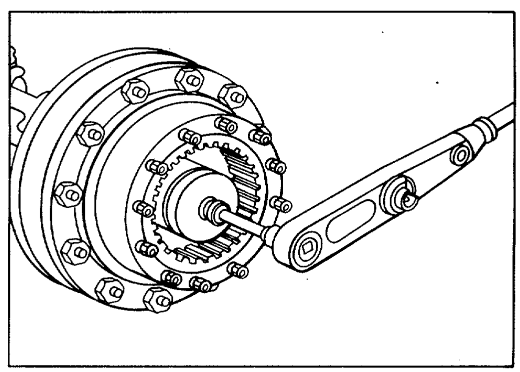
1. On axles other than the PR-50 and PS-50 series, tighten the adjusting nut against the ring gear hub to 400 lb ft (542 Nm) while the wheel is being rotated (refer to Fig. 6). On PR-50 and PS-50 series axles, adjust the nut to 100 lb ft (136 Nm) while the wheel is being rotated (refer to Fig. 6). Rotate the wheel in both directions to make sure bearings and related parts are fully seated.

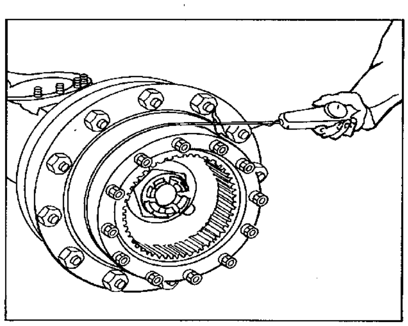
2. Back off adjusting nut ¼ turn to relieve preload on bearings.

3. If wheel bearings have been replaced with new bearings, check the rotating torque (not starting torque) by means of a pull scale and cord (refer to Fig. 7) and advance the adjusting nut in small increments until the proper preload for the particular axle model is obtained as follows:

AXLE MODEL	PRELOAD TORQUE
PR-50, PR-60	3 to 5 lb ft
PR-100	4 to 8 lb ft
PR-150	5 to 9 lb ft
PR-200	5 to 9 lb ft
PR-250	6 to 10 lb ft
PR-300	8 to 12 lb ft
PR-500	10 to 14 lb ft
PR-700	14 to 18 lb ft







NOTE

The above torque specifications allow for the drag of the hub spindle oil seal. However, if a felt dust seal is used in the inside of the brake drum, the torque specifications should be increased by 5 lb ft.

If wheel bearings are being reused, they should be put back in same position as before. Advance the adjusting nut in small increments and check rotating torque until an increase is noted. If increase is slight, install nut lock in this position or back off nut enough to install nut lock. If increase is appreciable, back off nut until increase is only slight or none and then install nut lock.

4. If it is not convenient to remove the wheels of the vehicle, check the wheel bearing preload torque as shown above (refer to Fig. 8). The extension (see inset) permits a reading to be taken without interference from the tire.

5. Bearing preload torque is figured by multiplying the radius (the distance from the center of the wheel to the center of the extension) by the reading on the pound scale.

For Example: Assume the distance from the center of the wheel to the center of the extension is 9 inches and the reading on the pound scale is 7 pounds (refer to Fig. 8 and 9). Multiplying 9 inches by 7 pounds, we get 63-pound inches. Since our preload specifications are listed in pound feet (lb ft), we simply divide the 63-pound inches by 12 and arrive at a reading of 5.25-pound feet.

This method of converting pound inches to pound feet also applies to Step 3 above.

ASSEMBLE PLANETARY SPIDER (Refer to Fig. 10.)

1. Place the planetary spider cage on a bench or block up on metal plates.

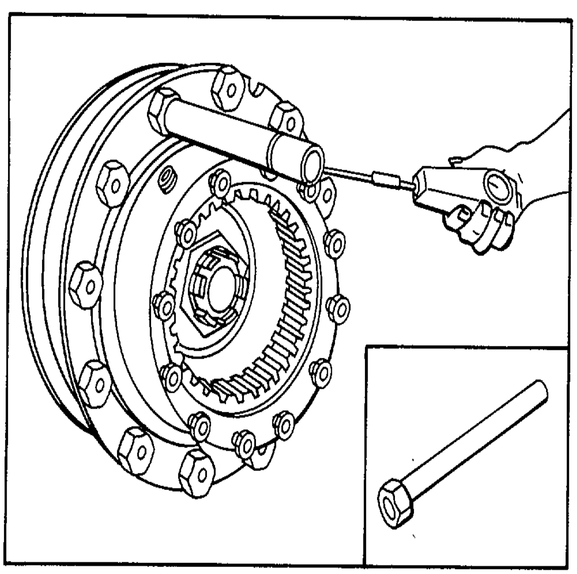


Figure 8.

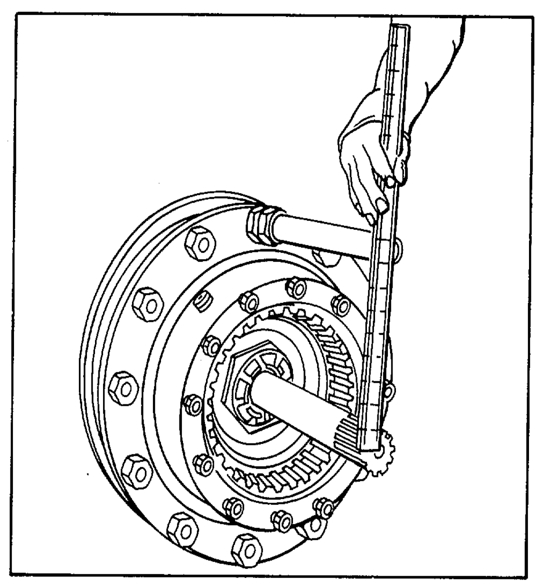


Figure 9.

REASSEMBLY AXLE

2. Align inner thrust washer hole with planet pinhole so that locating tab of washer lies in spider indent.

3. Slide in planet gear and outer thrust washer and align holes.

4. Press in the planet pin, small diameter end first.

5. Outer end of pins must be turned so that the machined flat is to the outside of hub circle. This not only allows cover clearance but also properly locates the planet pin oiling flat.

6. Proceed in the same manner with the second and third sets of planet pinions and thrust washers.

7. Planet pins should be pressed through until the shoulder of pin butts thrust washer.

INSTALL SPIDER AND PINION ASSEMBLY

1. Install spider to hub gasket after making sure that all hub spider studs are properly seated.

2. Start the spider and pinion assembly, aligning teeth of planet pinions with sun gear and ring gear teeth.

3. Align hub studs with spider holes and push spider assembly onto studs against hub gasket.

4. Install spider lockwashers and nuts.

5. Tighten nuts to correct torque.

INSTALL COVER

1. Install new spider to cover gasket against spider. It will be necessary to hold the gasket in place with a gasket cement so that the gasket hole may be aligned with the spider holes.

2. Install the spider cover with capscrews and lockwashers. Fill arrow must be in line with hub fill plug (refer to Fig. 11).

3. Tighten cover capscrews to correct torque.

LUBRICATION

1. Turn the complete hub and drum assembly so that the fill plug is at the top (refer to Fig. 11).

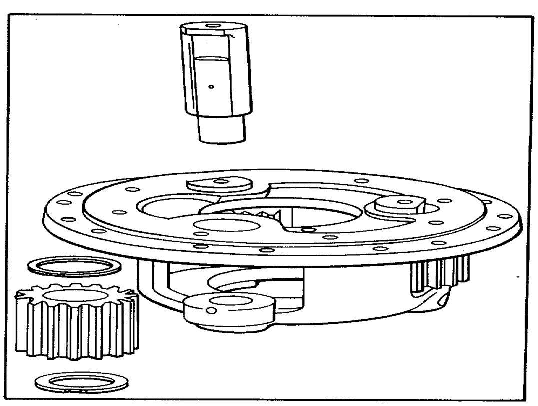


Figure 10.

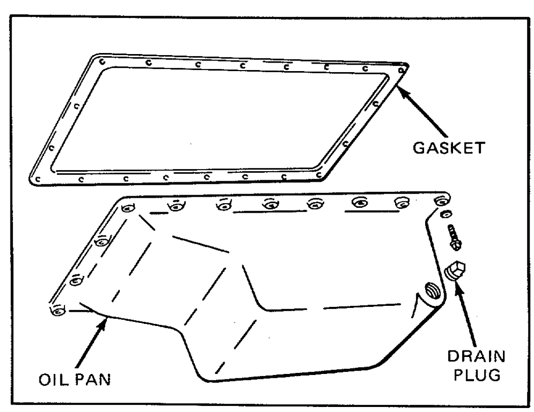


Figure 11.

2. Remove the fill plug and the oil level plug in the cover (refer to Fig. 11).

3. Fill wheel end planetary hub through fill hole with SAE-90 multipurpose lubricant until lubricant appears at the oil level hole. Reinstall fill and oil level hole plugs and tighten securely.

Recommended lubricant for planetary axle outer ends is multipurpose gear lubricant SAE-90 Rockwell Specification 0-64 for both summer and winter use.

Recommended lubricant for planetary axle carrier drive units is multipurpose gear lubricant SAE-140 Rockwell-Standard Specification 0-65 or multipurpose gear lubricant SAE-90 Rockwell-Standard Specification 0-64 as optional, depending on climatic conditions. (See *Field Maintenance Manual Number 1 under Multipurpose Gear Lubricants*.)

In low-speed and short-cycle type operation, where the lubricant temperature is likely to stay relatively low, it will usually be possible to use an SAE-90 lubricant in the housing bowl as well as in the wheel ends. In long-haul, sustained-speed type operations where the lubricant temperature is likely to run considerably higher, it will usually be advisable to use an SAE-140 lubricant in the housing bowl.

Recommended lubricant for planetary steering knuckles is wheel bearing lubricant grease NLGI Grade No. 2.

NOTE

Planetary axles without oil seals, to separate the wheel ends from the housing bowl, should use S.A.E. 90 (R.S. specification 0-64) lubricants only.

All SPR planetary units should use S.A.E. 90 lubricants (R.S. specification 0-64) in planetary outer ends and S.A.E. 140 (R.S. specification 0-65 as standard and 0-64 as optional) in the housing bowl.

TABULATION OF TORQUE LIMITS

CAPSCREWS

LOCATION	DIA	THDS..	TORQUES MIN.	TORQUES MAX	LOCATION	DIA	THDS.	TORQUES MIN.	TORQUES MAX.
Planetary spider cover	7/16" ½"	14 13	53 81	67 104	Brake chamber bracket	5/8" ¾"	11 10	160 290	205 370
Steering bear-ing cap	½" 5/8" 7/8"	13 11 14	81 160 510	104 205 655	Brake drum to hub	5/8" ¾" 7/8" 1"	11 10 14 14	160 290 510 780	205 370 655 1000
Planetary ring gear lock	5/16" 3/8" 7/16"	24 16 14	21 33 53	27 43 67	Brake cam-shaft collar	½"	13	81	104

BOLTS AND STUD NUTS									
			TORQUES					TORQUES	
LOCATION	DIA.	THDS.	MIN.	MAX	LOCATION	DIA.	THDS	MIN.	MAX
Planetary spider to hub	½" ¾"	13 10	81 290	104 370	Tie rod clamp	½" 5/8"	20 18	92 185	118 235
Steering knuckle to flange	7/16" 9/16" ¾"	14 12 10	53 116 290	67 149 370	Tie rod ball	¾" 1" 1-1/8" 1 ¼ 1 ¼	16 14 12 12 18	320 780 1120 1620 1/8"	415 1000 1420 1975 2065
Spindle to housing	5/8" 7/8" 1"	18 14 14	185 510 780	235 655 1000	Steering arm arm ball	¾" 1" 1 1/8" 1 ¼" 1 ¼"	16 12 12 12 18	320 780 1120 1540 1620	415 1000 1420 1975 2065
Steering and steering bearing cap	½" 5/8" ¾" 7/8"	13 11 10 14	12 81 160 290 510	104 205 370 655					
Trunnion socket to housing	9/16" ¾" 7/8"	12 10 14	116 290 510	149 370 655	Steering knuckle companion housing	½" ½"	13 20	81 92	104 118
					Carrier to housing	7/16." ½" 5/8"	14 13 11	53 81 160	67 104 205

Torques given apply to parts coated with machine oil; for dry (or "as rec'd") parts increase torques 10%; for parts coated with multipurpose gear oil decrease torques 10%. Nuts on studs to use same torque as for driving the stud.

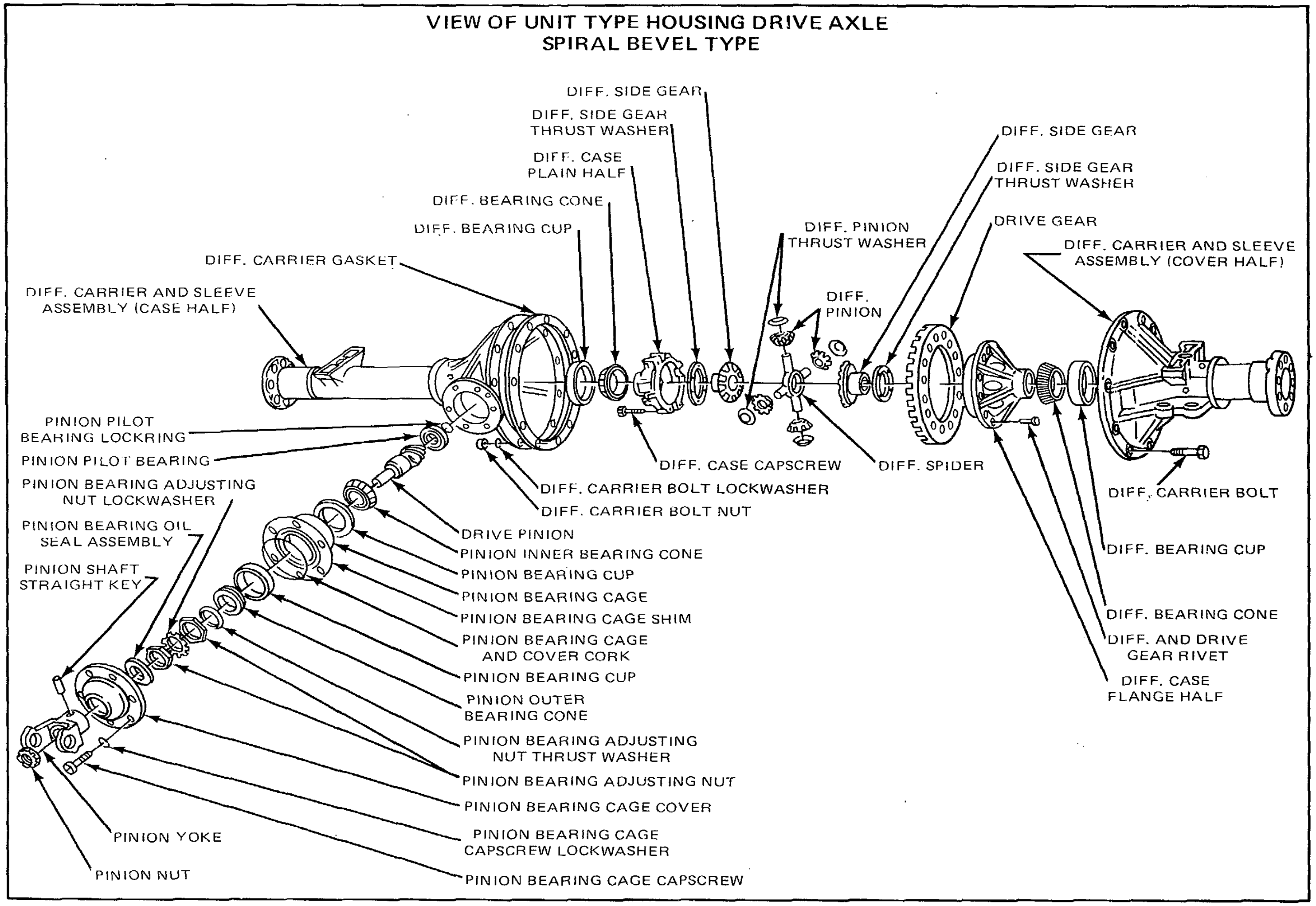

VIEW OF UNIT TYPE HOUSING DRIVE AXLE
SPIRAL BEVEL TYPE
DIFF. SIDE GEAR
DIFF. SIDE GEAR THRUST WASHER
DIFF. CASE PLAIN HALF
DIFF. BEARING CONE
DIFF. BEARING CUP
DIFF. CARRIER GASKET
DIFF. CARRIER AND SLEEVE ASSEMBLY (CASE HALF)
DIFF. PINION THRUST WASHER
DIFF. PINION
DIFF. SIDE GEAR
DIFF. SIDE GEAR THRUST WASHER
DRIVE GEAR
DIFF. CARRIER AND SLEEVE ASSEMBLY (COVER HALF)
PINION PILOT BEARING LOCKRING
PINION PILOT BEARING
PINION BEARING ADJUSTING NUT LOCKWASHER
PINION BEARING OIL SEAL ASSEMBLY
PINION SHAFT STRAIGHT KEY
DIFF. CASE CAPSCREW
DIFF. SPIDER
DIFF. CARRIER BOLT LOCKWASHER
DIFF. CARRIER BOLT NUT
DIFF. CARRIER BOLT
DRIVE PINION
PINION INNER BEARING CONE
PINION BEARING CUP
PINION BEARING CAGE
PINION BEARING CAGE SHIM
PINION BEARING CAGE AND COVER CORK
PINION BEARING CUP
PINION OUTER BEARING CONE
PINION BEARING ADJUSTING NUT THRUST WASHER
PINION BEARING ADJUSTING NUT
PINION BEARING CAGE COVER
PINION BEARING CAGE CAPSCREW LOCKWASHER
PINION BEARING CAGE CAPSCREW
PINION YOKE
PINION NUT
DIFF. BEARING CUP
DIFF. BEARING CONE
DIFF. AND DRIVE GEAR RIVET
DIFF. CASE FLANGE HALF

Figure 1.

DRIVE UNIT

CARE AND MAINTENANCE

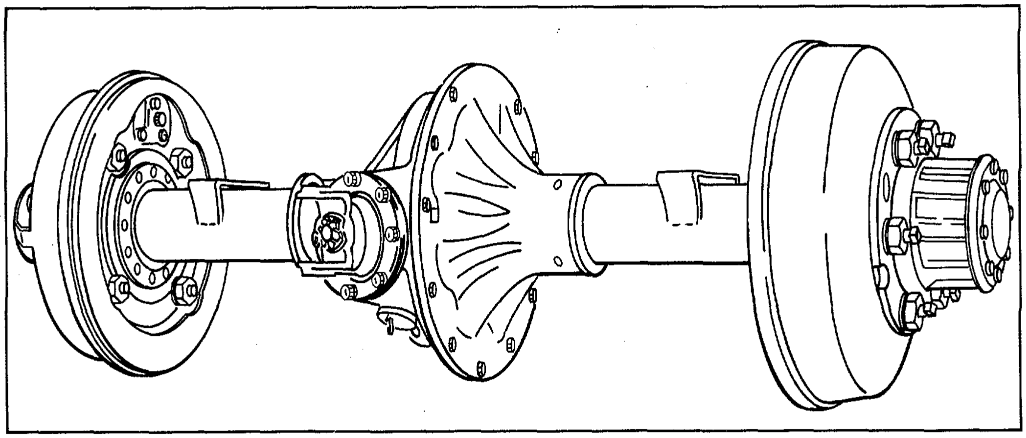


Figure 2.

Rockwell-Standard Company unit-type housing drive units are single- reduction drives of both spiral bevel and hypoid design. The differential and gear assembly is mounted on tapered roller bearings with the cups assembled in the case and cover halves of the housing. The straddle mounted pinion has two tapered roller bearings located forward of the pinion teeth and a radial bearing at the inner end.

Where the spiral bevel gear set is used, the flange or yoke is assembled on a tapered pinion shaft and the bearing pre load controlled by bearing adjusting and locknuts.

On hypoid geared units the pinion shaft is splined to accommodate the flange and the bearing pre load controlled by hardened and ground spacers of the correct thickness between the bearings. Bearings are retained in position by the companion flange nut. If desired, the spiral bevel type unit may be disassembled by removing only the cover half of the housing from the vehicle.

1. Remove plug from bottom of axle housing and drain lubricant.
2. Disconnect universal at pinion shaft.
3. Disconnect brakes.
4. Remove spring clips.
5. Remove axle from under vehicle.
6. Remove the axle shaft stud nuts, lockwashers, and tapered dowels.

IMPORTANT

To loosen the dowels, hold at 1 ½-inch diameter brass drift against the center of the axle shaft head, INSIDE THE CIRCULAR DRIVING LUGS. Strike the drift a sharp blow with a 5- to 6- pound hammer or sledge. A 1 ½-inch diameter brass hammer is an excellent and safe drift.

CAUTION

Do not hit the circular driving lugs on the shaft head-this may cause the lugs to shatter and splinter. Do not use chisels or wedges to loosen the shaft or dowels-this will damage the hub, shaft and oil seal.

7. Remove axle shafts and carefully remove outer oil seal assemblies.

8. Remove wheels.

9. Place axle assembly in heavy vise, holding by the tube on the case half.

DISASSEMBLE AXLE

1. Before disassembling, place length of pipe or suitable support, slightly smaller than axle shaft splines, approximately two-thirds through axle from the case side to prevent dropping the differential assembly.

2. Remove bolts, nuts, and washers from case and cover and remove cover half.

3. Remove differential and gear assembly.

4. Remove pipe.

DISASSEMBLE DIFFERENTIAL AND GEAR ASSEMBLY

1. If original identification marks are not clear, mark differential case halves with a punch or chisel (refer to Fig. 3) before disassembling, for correct alignment when reassembling.

2. Cut lock wire, remove bolts or capscrews, and separate case halves (refer to Fig. 3).

3. Remove spider, pinions, side gears, and thrust washers (refer to Fig. 3).

4. Remove rivets and separate gear and case if required (refer to Fig. 4).

    a. Carefully centerpunch rivets in center of head.

    b. Use drill 1/32-inch smaller than body of rivet to drill through head.

    c. Press out rivets.

5. Remove differential bearings with bearing puller if necessary to replace (refer to Fig. 5).

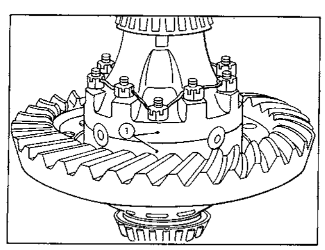


Figure 3.

REMOVE PINION AND CAGE ASSEMBLY

The differential and gear assembly must be removed before the pinion and cage assembly can be disassembled.

1. Secure yoke with holding tool and remove pinion shaft nut and washer (refer to Fig. 6).

2. Insert puller through yoke and remove (refer to Fig. 7).

3. Remove pinion bearing cover and oil seal assembly.

4. Remove pinion and cage assembly using puller screws in holes provided (refer to Fig. 8).

Driving pinion from inner end with a drift will damage the bearing lockring groove.

DISASSEMBLE PINION AND CAGE ASSEMBLY

Hypoid-Splined Shaft

1. Tap shaft from cage with soft mallet or press shaft from cage.

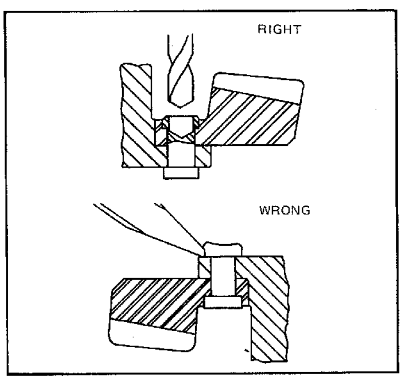


Figure 4. Removing Gear Rivet.

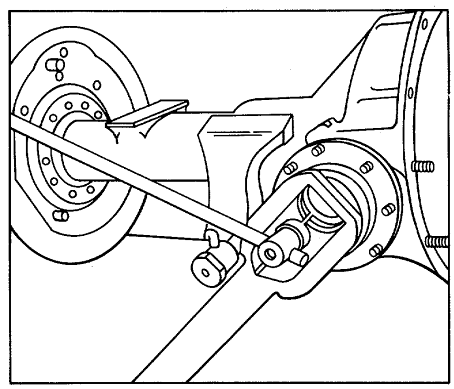


Figure 6.

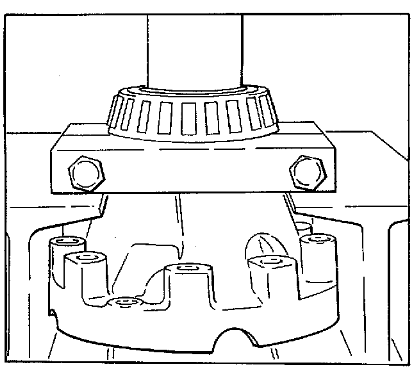


Figure 5.

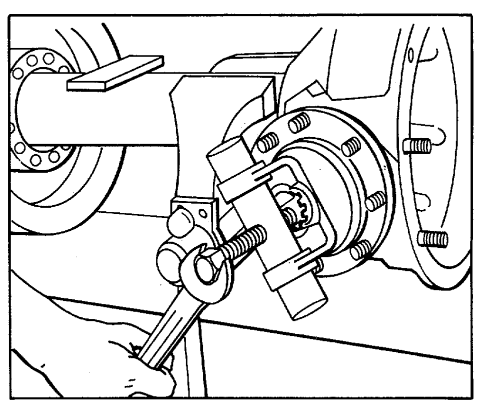


Figure 7.

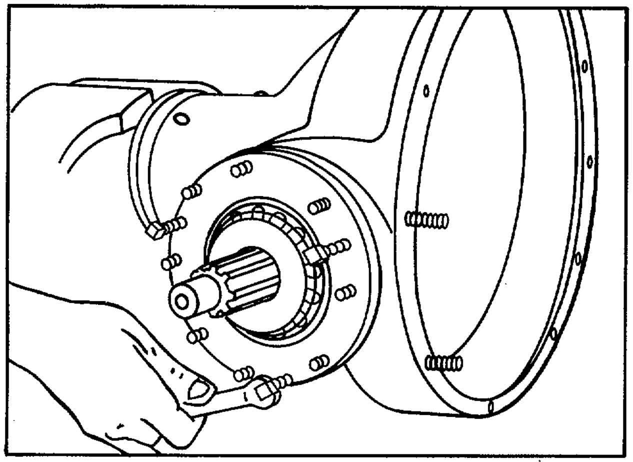


Figure 8.

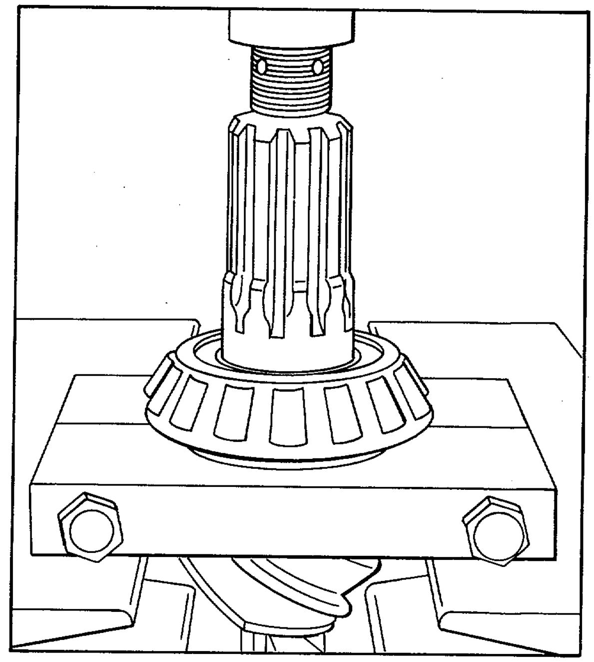


Figure 9.

2. Remove outer bearing from cage.

3. Remove spacer or spacer combination from pinion shaft.

4. Remove rear thrust bearing and radial bearing with bearing puller if necessary to replace (refer to Fig. 9).

5. Remove oil seal assembly from bearing cover.

6. If necessary to remove differential bearing cups, wire the selective spacers which are behind the cups to their respective axle halves.

Spiral Bevel - Tapered Shaft

1. Straighten lockwasher and remove locknut, washer, adjusting nut, and thrust washer.

2. Tap pinion out of cage with soft mallet or press shaft from cage.

3. Remove bearing from cage.

4. Remove bearings from shaft with suitable puller if necessary (refer to Fig. 9).

5. Remove oil seal assembly from bearing cover.

PREPARE FOR REASSEMBLY

CLEAN

Parts having ground and polished surfaces such as gears, bearings, shafts, and collars, should be cleaned in a suitable solvent such as kerosene or diesel fuel oil.

GASOLINE SHOULD BE AVOIDED.

DO NOT clean these parts in a hot solution tank or with water and alkaline solutions such as sodium hydroxide, orthosilicates, or phosphates.

We do NOT recommend steam cleaning assembled drive units after they have been removed from the housing.

When this method of cleaning is used, water is trapped in the cored passage of the castings and in the close clearances between parts as well as on the parts. This can lead to corrosion (rust) of critical parts of the assembly and the possibility of circulating rust particles in the lubricant. Premature failure of bearings, gears and other parts can be caused by this practice. Assembled drive units cannot be properly cleaned by steam cleaning, dipping or slushing. Complete drive-unit disassembly is a necessary requisite to thorough cleaning.

ROUGH PARTS

Rough parts such as differential carrier castings, cast brackets, and some brake parts may be cleaned in hot solution tanks with mild alkali solutions providing these parts are not ground or polished. The parts should remain in the tank long enough to be thoroughly cleaned and heated through. This will aid the evaporation of the rinse water. The parts should be thoroughly rinsed after cleaning to remove all traces of alkali.

WARNING

Exercise care to avoid skin rashes and inhalation of vapors when using alkali cleaners.

COMPLETE ASSEMBLIES

Completely assembled axles may be steam cleaned on the outside only, to facilitate initial removal and disassembly, providing all openings are closed. Breathers, vented shift units, and all other openings should be tightly covered or closed to prevent the possibility of water entering the assembly.

DRYING

Parts should be thoroughly dried immediately after cleaning. Use soft, clean, lintless, absorbent paper towels or wiping rags free of abrasive material, such as lapping compound, metal filings or contaminated oil. Bearings should never be dried by spinning with compressed air.

CORROSION PREVENTION

Parts that have been cleaned, dried, inspected and are to be immediately reassembled should be coated with light oil to prevent corrosion. If these parts are to be stored for any length of time, they should be treated with a good RUST PREVENTIVE and wrapped in special paper or other material designed to prevent corrosion.

INSPECT

It is impossible to overstress the importance of careful and thorough inspection of drive unit parts prior to reassembly. Thorough visual inspection for indications of wear or stress, and the replacement of such parts as are necessary will eliminate costly and avoidable drive unit failure.

1. Inspect all bearings, cups and cones, including those not removed from parts of the drive unit and replace if rollers or cups are pitted or damaged in any way. Remove parts needing replacement with a suitable puller or in a press with sleeves.

Avoid the use of drifts and hammers. They may easily mutilate or distort component parts.

2. Inspect first reduction bevel or hypoid and second reduction spur gears for wear or damage. Gears which are pitted, galled, or worn or broken through case hardening should be replaced.

When necessary to replace the pinion or gear of a spiral bevel or hypoid gear set, the entire gear set should be replaced. We assume no responsibility for gears of these types when replaced in any other manner.

3. Inspect the differential assembly for the following:

a. Pitted, scored, or worn thrust surfaces of differential case halves, thrust washers, spider trunnions, and differential gears.

Thrust washers must be replaced in sets. The use of a combination of old and new washers will result in premature failure.

b. Wear or damage to the differential pinion and side gear teeth.

Always replace differential pinions and side gears in sets.

4. Spur pinions for wear or damage to teeth.

5. Check end of pinion for indications of brinelling caused by worn splines. Replace the parts if the splines of the pinion and/or thru-shaft are worn, permitting movement of the pinion on the thru-shaft.

6. Axle shafts for indications of torsional fractures and runout. Axle shafts should be inspected between centers to ascertain the amount of runout of the ground surfaces. Runout at the shaft flange and splines should not exceed . 005-inch total indicator reading.

REPAIR

1. Replace all worn or damaged parts. Hex nuts with rounded corners, all lockwashers, oil seals, and gaskets should be replaced at the time of overhaul.

Use only genuine Rockwell-Standard parts for satisfactory service. For example, using gaskets of foreign material generally leads to mechanical trouble due to variations in thickness and the inability of certain materials to withstand compression, oil, etc.

2. Remove nicks, mars, and burrs from machined or ground surfaces. Threads must be clean and free to obtain accurate adjustment and correct torque. A fine mill file or India stone is suitable for this purpose. Studs must be tight prior to reassembling the parts.

3. If necessary, install new differential pinion bushings where used as follows:

a. Remove worn bushing. The bushing may be split with a hacksaw and the halves easily removed.

b. Remove burrs or sharp corner from inner edge of pinion bore to prevent shearing or buckling of bushing on installation.

c. Place pinion on anvil. Position bushing in inner end of pinion bore and press squarely into position. Use adaptor with correct size offset to fit bushing (refer to Fig. 10).

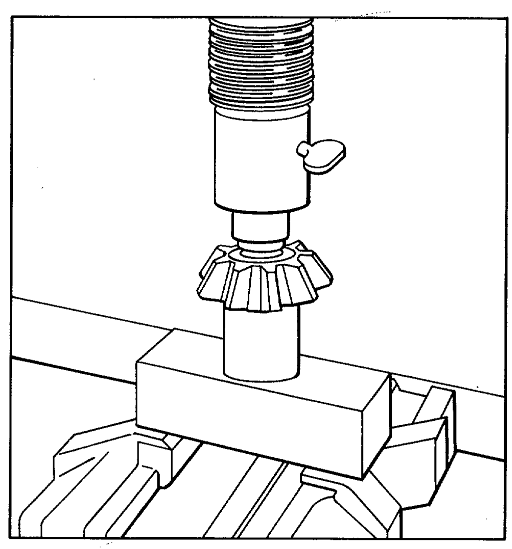


Figure 10.

d. Use bar to press burnishing ball through bushing (refer to Fig. 11).

If desired, the bar may be shortened to permit the use of a bench vise to install and burnish bushing (refer to Fig. 12).

4. When assembling component parts use a press where necessary. Avoid hammering.

5. Tighten all nuts to specified torque (refer to Torque Specifications), following service instructions.

Lock wire must not be brittle; use soft iron wire to prevent possibility of wire breakage.

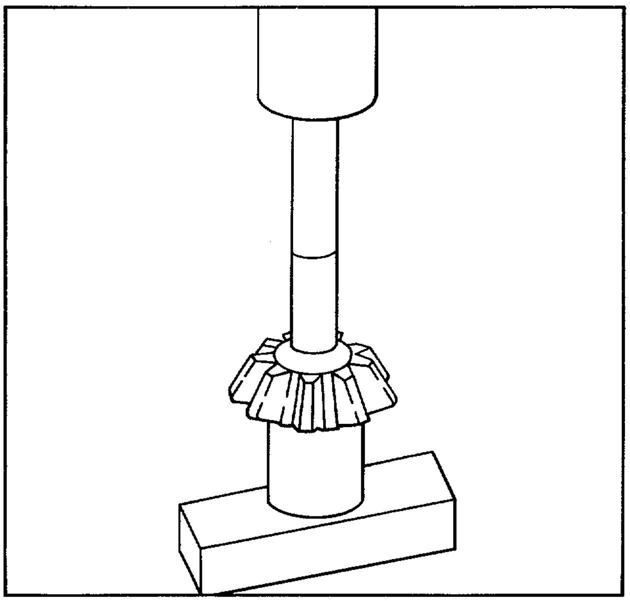


Figure 11.

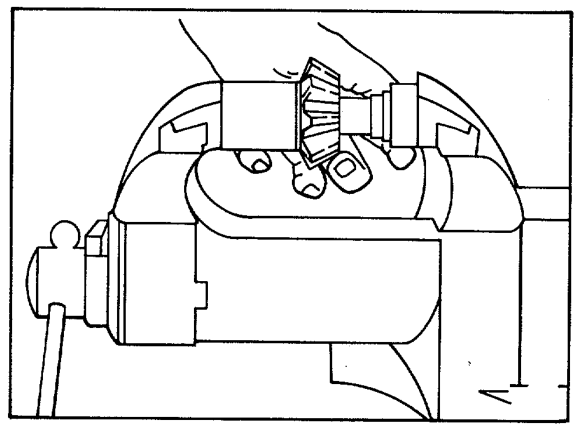


Figure 12.

REASSEMBLE AXLE

REASSEMBLE PINION AND CAGE ASSEMBLY

Hypoid - Splined Shaft

When a new pinion cage is required, the bearing and cage assembly furnished for service purposes should be used. This includes the cage with bearing cups assembled, bearing cones and the selective spacer required to obtain the correct bearing preload.

The used bearing cones should be removed from the pinion shaft and the new bearings and spacer used in the assembly.

1. Press rear thrust and radial bearings firmly against the pinion shoulders with a suitable sleeve (refer to Fig. 1).

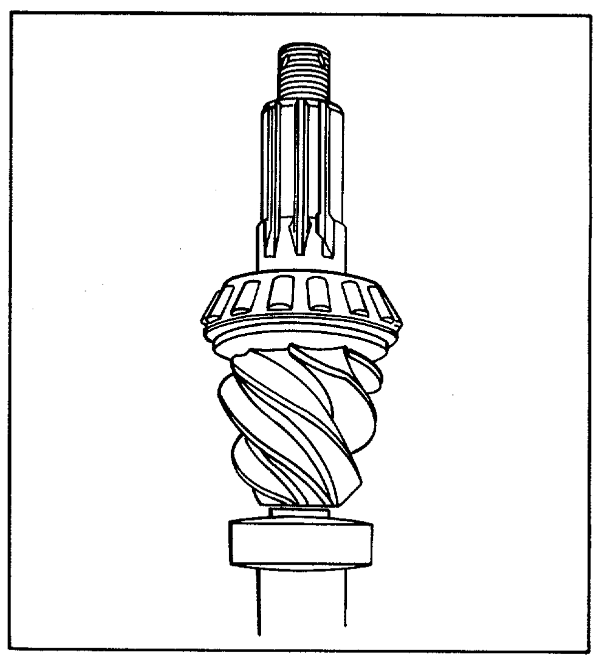


Figure 1.

2. Install radial bearing lockring and squeeze ring into pinion shaft groove with pliers.

3. If new cups are to be installed, press firmly against pinion bearing cage shoulders.

4. Lubricate bearings and cups with light machine oil.

5. Insert pinion and bearing assembly in pinion cage and position spacer or spacer combination over pinion shaft.

6. Press front bearing firmly against spacer.

7. Rotate cage several revolutions to assure normal bearing contact.

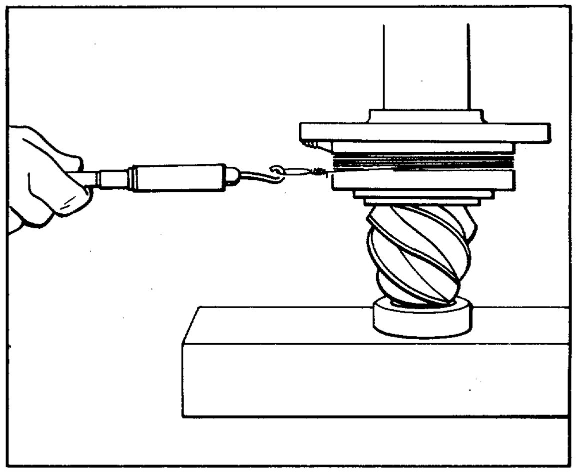


Figure 2.

8. While in press at 25,000 pounds pressure, check bearing preload torque. Wrap soft wire around cage and pull on horizontal line with pound scale. If a press is not available, the yoke may be installed and the pinion nut tightened to specified torque for checking (refer to Fig. 2).

NOTE

If rotating torque is not within 5 to 15 lb in, use thinner spacer to increase or thicker spacer to decrease preload.

Example: Assuming pinion cage diameter to be 6 inches the radius would be 3 inches and with 5 pounds pull would equal 15 lb in preload torque.

9. Press yoke against forward bearing and install washer and pinion shaft nut.

10. Place pinion and cage assembly over carrier studs, hold yoke and tighten pinion shaft nut to specified torque. The yoke must be held with a suitable tool or fixture to tighten nut.

11. Recheck pinion bearing preload torque.

NOTE

If rotating torque is not within 5 to 15 lb in, repeat the foregoing procedure.

12. Hold yoke and remove pinion shaft nut and yoke.

13. Lubricate pinion shaft oil seal and cover outer edge of seal body with a non-hardening sealing compound. Press seal against cover shoulder with seal driver (refer to Fig. 3).

14. Install new gasket and bearing cover.

15. Press yoke against forward bearing and install washer and pinion shaft nut (refer to Fig. 4).

16. Tighten to specified torque (refer to *Torque Specifications*) and install cotter key. Do not back off nut to align cotter key holes (refer to Fig. 5).

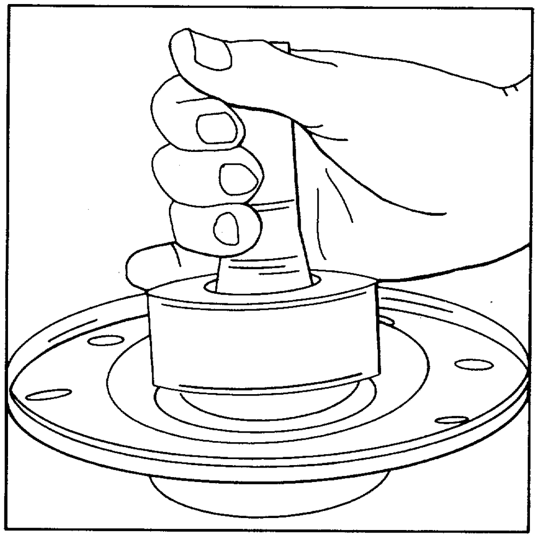


Figure 3.

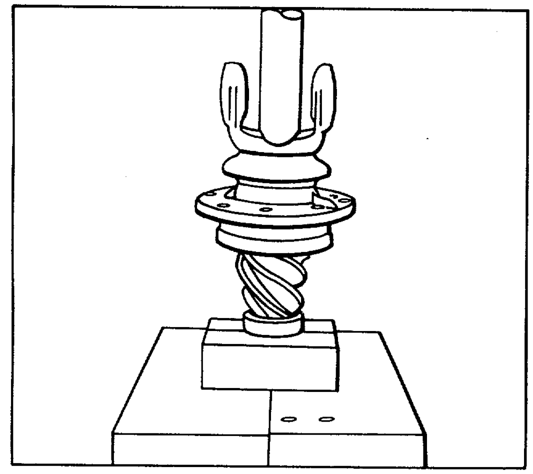


Figure 4.

Spiral Bevel - Tapered Shaft

1. Press rear thrust and radial bearings firmly against the pinion shaft shoulder.

2. Install radial bearing lockring and squeeze ring into pinion shaft groove with pliers.

3. If new cups are to be installed, press firmly against pinion cage shoulders.

4. Lubricate bearings and cups with light machine oil.

5. Install forward bearing, thrust washer and adjusting nut.

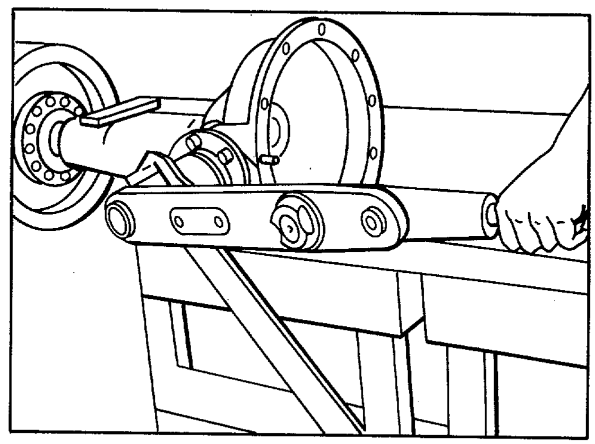


Figure 5.

6. Install new lockwasher and the locknut.

7. Adjust pinion bearing preload to 5 to 15 lb in with locknut tightened securely against washer.

CAUTION

The locknut must be tight to secure the correct preload.

8. Bend lockwasher when correct adjustment has been secured.

9. Lubricate pinion shaft oil seal and cover outer edge of seal body with a non-hardening sealing compound. Press seal against cover shoulder with seal driver.

10. Install new cork gasket and bearing cover. Cover should be carefully installed to prevent cutting seal on keyway.

11. Install key, press flange on taper, and install washer and pinion shaft nut.

12. Tighten to the correct torque and install cotter key.

CAUTION

Do not back off nut to align cotter key holes.

ASSEMBLE DIFFERENTIAL AND BEVEL GEAR

1. Rivet bevel gear to case half with new rivets.

NOTE

If a new gear or differential case is to be used in the assembly, the rivet holes in the gear and case should be checked for alignment and line reamed if necessary. The gear must be tight on the case pilot and riveted flush with the differential case flange. Check with a 0.002-inch feeler gauge.

Rivets should not be heated, but should be upset cold. When the correct rivet and rivet set is used the head being formed will be at least 1/8 inch larger in diameter than the rivet hole.

The head will then be approximately the same height as the preformed head. The formed head should not exceed 1/16 inch less than the preformed head as excessive pressure will cause distortion of the case holes and result in gear eccentricity.

2. Lubricate differential case inner walls and all component parts with axle lubricant.

3. Position thrust washer and side gear in bevel gear and case half assembly.

4. Place spider with pinions and thrust washers in position (refer to Fig. 6 and 7).

5. Install component side gear and thrust washer.

6. Align mating marks, position component case half, and draw assembly together with four bolts or capscrews equally spaced.

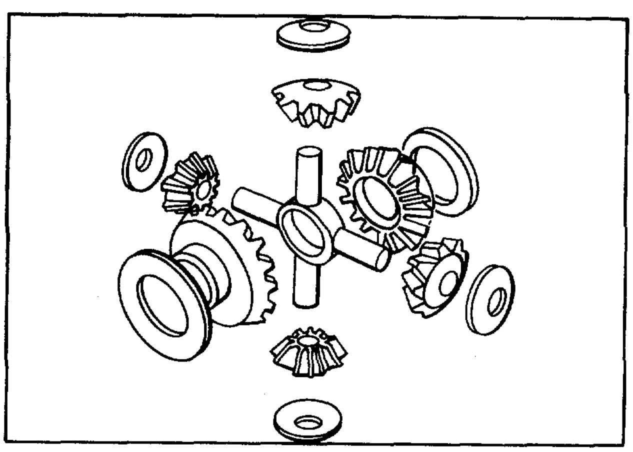


Figure 6.

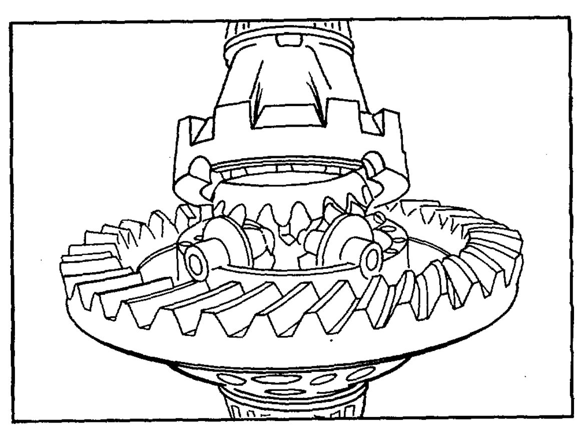


Figure 7.

7. Check assembly for free rotation of differential gears and correct if necessary.

8. Install remaining bolts or capscrews, tighten to specified torque and thread with lock wire.

9. If bearings are to be replaced, press squarely and firmly on differential case halves.

DIFFERENTIAL BEARING PRELOAD AND GEAR LASH ADJUSTMENTS

On all hypoid-geared drive units the differential bearing preload and gear lash adjustments are obtained by the use of hardened and ground spacers of the correct thickness located between the differential bearing cups and the axle housing. On this type assembly, no shim pack is required between the pinion cage and axle housing.

Where spiral bevel gears are used, the housing is machined within limits which impose the correct differential bearing preload and gear lash when the unit is assembled.

ADJUST DIFFERENTIAL BEARING PRELOAD

Hypoid-Splined Shaft

1. Remove thrust block using drift to drive pin out of cover.

2. Install differential bearing spacers in the original positions if new bearing cups are installed (refer to Fig. 8).

NOTE

Spacers must be installed with the chamfered edge toward the machined surfaces in the housing.

3. Insert pipe used for disassembling through case half.

4. Position differential and gear assembly over pipe with gear facing the case half and slide into position (refer to Fig. 9).

5. Install new gasket over case flange.

6. Position cover half over pipe and draw axle halves together with six bolts equally spaced.

7. Check differential and gear assembly end play with dial indicator through thrust block pinhole against gear (refer to Fig. 10).

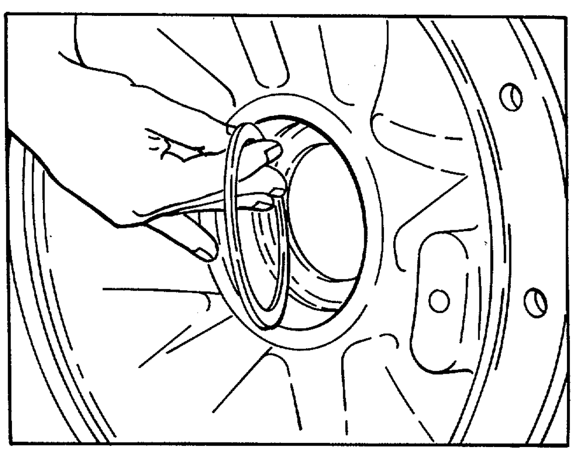


Figure 8.

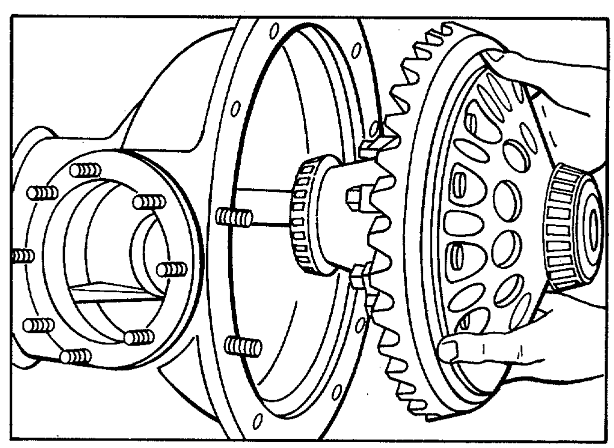


Figure 9.

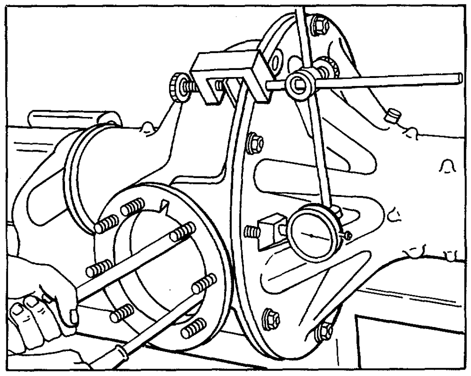


Figure 10.

NOTE

Both the differential bearing preload and gear lash are controlled by selective spacers, available in increments of 0.003 inch, which are installed between the differential bearing cups and the case and cover halves of the axle housing.

Bearing preload may be increased or decreased by using a thicker or thinner spacer respectively in the cover half of the assembly.

The gear may be moved toward the pinion, decreasing the gear lash, by decreasing the thickness of the spacer in the case half and increasing the thickness of the spacer by the same amount in the cover half. Reversing this transposition will move the gear away from the pinion and increase the gear lash.

The correct preload of 0.006-inch to 0.010-inch tight is obtained as follows:

a. Increase or decrease the thickness of the spacer used in the cover half to obtain a freely rotating gear with from 0.000 inch to 0.005 inch end play.

b. Remove spacer in cover half and install a spacer 0.006-inch plus the end play thicker than the spacer used to obtain the adjustment in the above paragraph.

c. If a new gear or case has been installed, check runout at back face of gear. Correct and recheck if runout exceeds 0.005 inch.

d. When adjustment is satisfactory, remove cover and move differential and gear out on support sufficient to permit installation of pinion and cage assembly.

8. Install thrust block and pin.

INSTALL PINION AND CAGE ASSEMBLY

1. Coat cage flange contact surface with non-hardening sealing compound. Position cage assembly over studs and tap into position with soft mallet.

2. Install lockwashers and stud nuts. Tighten to specified torque.

CHECK AND ADIJUST GEAR LASH

Hypoid - Splined Shaft

1. Install differential and gear assembly and assemble cover using new gasket with six bolts equally spaced. Tighten to specified torque.

2. Check gear lash with dial indicator on universal joint yoke 2 inches from pinion shaft center. An indicator reading of between 0.013 inch and 0.033 inch will show the recommended backlash of between 0.006 inch and 0.012 inch is present in the gear set (refer to Fig. 11).

3. Transpose spacers used in both the case and cover, decreasing the thickness of the spacer used on the side in the direction which the gear is to be moved and increasing the thickness of the opposite spacer exactly the same amount as required to obtain the correct gear lash.

4. Install remaining bolts, washers and nuts in housing assembly and tighten all nuts in bolt circle to specified torque (refer to *Torque Specifications*).

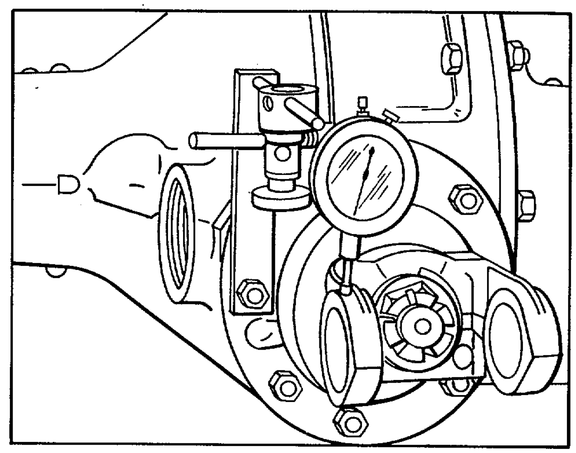


Figure 11.

INSTALL CAGE AND DIFFERENTIAL ASSEMBLIES

Spiral Bevel - Tapered Shaft

1. Coat cage flange contact surface with non-hardening sealing compound. Position cage assembly over studs and tap into position with soft mallet.

2. Install lockwashers and stud nuts. Tighten to specified torque.

3. Install differential and gear assembly using new gasket. Tighten nuts to specified torque (refer to *Torque Specifications).*

INSTALL AXLE ASSEMBLY IN VEHICLE

1. Position axle assembly under vehicle and install spring clips.

2. Clean and lubricate hub cavity and wheel bearings if required.

3. Install wheels and adjust wheel bearings.

4. Install new outer oil seal assembly if required.

5. Install axle shafts using new gaskets. Tighten stud nuts to specified torque.

6. Connect brakes.

7. Connect universal at pinion shaft.

LUBRICATION

1. Fill axle to correct level with specified lubricant. (See Field Maintenance Manual No. 1 for oil capacities.)

2. Lubricate universal joint.

3. Jack up BOTH rear wheels and operate vehicle for five minutes in HIGH transmission gear at approximately 25 to 30 miles per hour to assure satisfactory lubrication to all parts of the assembly.

CAUTION

Do not operate with one wheel jacked up. Operation in this manner will result in overheating the differential spider with resultant galling or shearing of the spider pins.

Both wheel brakes should be free to allow both wheels to rotate at approximately the same speed.

TORQUE SPECIFICATIONS

LOCATION	DIAMETER	NO. THREADS	TORQUE - LB. FT.	
			MIN.	MAX.
Cover to case bolt nuts	3/8"	16	27	35
	3/8"	24	31	39
	7/16"	20	42	54
	1/2"	20	75	96
Pinion cage capscrews and stud nuts	3/8"	16	27	35
	3/8"	24	31	39
	7/16"	20	42	54
	9/16"	12	94	120
Differential case bolt nuts and capscrews	3/8"	16	33	43
	1/2"	13	81	104
	1/2"	20	92	118
Pinion shaft nuts	7/8"	20	175	200
	1"	20	300	400
Gear to case capscrews	3/8"	24	38	49

Torques given apply to parts coated with machine oil; for dry (or "as received") parts increase torques 10%; for parts coated with multi-purpose gear oil decrease torques 10%. Nuts on studs to use same torque as for driving the stud.

APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
01	ENGINE								
0100	Engine Assembly	Test		2.0				1,2,3,4	
		Service	0.1						
		Replace			16.0				
		Repair			21.0				
		Overhaul				48.0			
	Engine Mounts	Replace		3.0					
0101	Cylinder Block	Test				5.0		1,2,3,4	
		Replace				40.0			
		Repair				20.0			
	Cylinder Sleeve	Replace				3.0			
	Cylinder Head	Replace			4.0				
		Repair				4.0			
		Overhaul				8.0			
0102	Crankshaft	Replace				5.0		1,2,3,4	
	Main Bearings	Replace				4.0			
	Drive Pulley	Replace	2.0						
0103	Flywheel	Replace		3.0				1,2,3,4	

*The subcolumns are as follows:
C--operator/crew F--direct support
D--depot
O--organizational H--general support

APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELEID HIGH IMPACT, SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0104	Pistons & Connecting Rods	Replace				3.0		1,2,3,4	
		Repair				2.0			
	Rings and Bearing	Replace				0.5			
0105	Rocker Arms	Replace			0.5			1,2	
	Valve Springs	Test				0.8			
		Replace				0.3			
	Valves, Exhaust	Adjust			2.0				
		Replace				1.0			
		Repair				2.0			
	Camshaft, Bearings, and Gears	Replace				4.0			
0106	Oil Cooler							1,2	
		Service		0.2					
		Replace			1.0				
	Oil Pan	Replace			1.5				
		Repair			1.0				
	Oil Pump	Replace			0.8				
		Repair			2.0				

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ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT, SINGLE SMOOTH DRUM (CCE)

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	Oil Pressure Regulator	Adjust			0.2				
		Replace			0.5				
	Oil Filter Assy	Service		0.2					
		Replace			1.0				
	Oil Filter Element	Replace		0.5					
0108	Exhaust Manifold	Replace			1.0			1,2,3,4	
		Repair			1.0				
02	CLUTCH								
0200	Clutch Assembly	Replace			8.0			1,2,3,4	
		Repair			4.0				
	Drive Ring	Replace			8.0				
	Clutch Housing	Replace			6.0				
		Repair			2.0				
0202	Throw out Fork/ Bearings	Replace			6.0			1,2	
	Clutch Lever Shaft/ Linkage	Adjust		1.0					
		Replace			4.0				
		Repair			2.0				

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MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT, SINGLE SMOOTH DRUM (CCE)

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0205	Double Pump Drive Assy	Replace			8.0			1,2	
		Repair			4.0				
03	FUEL SYSTEM								
0301	Fuel Injector	Test			1.0			1,2	
		Replace			1.5				
0302	Fuel Pump	Replace		1.0				1,2	
		Repair				1.0			
0304	Air Cleaner	Service	0.4					1	
		Replace		1.0					
		Repair		0.5					
	Air Cleaner Element	Replace	0.5						
0305	Blower, Air Intake	Service		0.3				1	
		Replace			1.0				
		Repair			2.0				
	Air Shutdown	Adjust			0.5				
		Replace			1.5				
		Repair			2.0				

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ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

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0306	Fuel Tank	Service	0.2					1,2	
		Replace		1.5					
		Repair			2.0				
	Lines and Fittings	Replace		1.0					
		Repair		1.0					
0308	Governor, Engine Speed	Test			0.5			1,2	
		Adjust			0.5				
		Replace			1.0				
		Repair				2.0			
0309	Fuel Filters	Service	0.2					1	
	Fuel Filter Element	Replace		0.5					
0312	Throttle Control Linkage	Adjust		0.5				1	
		Replace		0.5					
		Repair		0.5					
04	EXHAUST SYSTEM								
0401	Muffler & Exhaust Pipes	Replace		1.0				1	
		Repair		1.0					

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MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

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05	COOLING SYSTEM								
0501	Radiator	Service	0.2					1	
		Replace			2.0				
		Repair				2.0			
0503	Thermostat	Replace		1.0				1	
	Hoses and Clamps	Replace		0.5					
0504	Water Pump	Replace		2.0				1	
		Repair			1.0				
0505	Fan Assembly	Replace		1.0				1	
		Repair			1.0				
	Fan Guard	Replace		1.0					
		Repair		1.0					
	Fan Belts	Inspect		0.1					
		Adjust		0.5					
		Replace		1.0					
06	ELECTRICAL SYSTEM								
0601	Alternator	Test		0.5				1,5	
		Replace		0.6					

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MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

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		Repair			1.5				
	Alternator Dr. Belt	Inspect		0.1					
		Adjust		0.5					
		Replace		1.0					
0603	Starting Motor	Test		0.5				1,5	
		Replace		1.0					
		Repair			1.5				
0607	Instrument Panel Accessories	Replace		0.5				1	
		Repair		0.5					
0608	Miscellaneous Electrical Items (switches, circuit breakers, etc)	Replace		0.5				1	
		Repair		0.5					
0609	Headlight Assembly	Replace		0.3				1	
		Repair		0.5					
	Headlight Lamp Units	Replace		0.3				1	
0610	Sending Units/ Warning Switches	Replace		0.5				1	
0611	Horn Assembly	Replace		0.5				1	
		Repair		0.5					

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MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

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0612	Battery	Test		0.3				1,5	
		Service	0.2						
		Replace		0.5					
	Battery Cables	Replace		0.4					
		Repair		0.5					
		Repair		0.5					
0613	Wiring Harness	Replace			1.0			1	
		Repair		1.0				5	
07	TRANSMISSION SYSTEM								
0700	Transmission Assembly	Test			2.0			1,2,3,4	
		Service		1.0					
		Replace			16 0				
		Repair			16.0				
		Overhaul				20.0			
6705	Gear Range Control	Service		0.3				1	
		Adjust		0.5					
		Replace		2.0					
		Repair		2.0					

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MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
0721	Hydraulic Oil Reservoir	Service	0.3					1,2	
		Replace			3.0				
		Repair			3.0				
	Hydraulic Oil Filter	Replace		1.0					
	Hydrostatic Pump (propelling)	Replace			2.0				
		Repair			2.0				
		Overhaul				4.0			
	Hydrostatic Motor (propelling)	Replace			1.5				
		Repair			2.0				
		Overhaul				4.0			
	Hydraulic Oil Cooler	Replace			2.0				
		Repair			2.0				
	Direction/Speed Control Assembly	Adjust		1.0					
		Replace		2.0					
		Repair		2.0					
	Pressure Relief Valve	Replace			1.0				

*The subcolumns are as follows:
C--operator/crew F--direct support D--depot
O--organizational H--general support

APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
	Lines and Fittings	Replace			1.0				
		Repair			1.0				
08	VIBRATORY DRIVE SYSTEM								
0801	Hydrostatic Pump (Vibratory)	Replace			2.0			1,2	
		Repair			2.0				
		Overhaul				4.0			
	Jack Shaft, Bearings, Coupling, and Sheave	Replace			2.0				
		Repair			2.0				
	V-Belt Drive Band	Inspect		0.2					
		Adjust		0.5					
		Replace		2.0					
	Driven Sheave Assy	Replace			3.0				
		Repair			3.0				
	Eccentric Shaft Assy	Service		0.5					
		Replace			8.0				
		Repair			8.0				
	Vibratory Control Assy	Adjust		1.0					

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APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
		Replace		2.0					
		Repair		1.0					
09	PROPELLOR SHAFT								
0900	Propeller Shaft Assy	Replace		1.5				1	
		Repair		1.0					
11	REAR AXLE								
1100	Rear Axle Assy	Replace			8.0				
		Repair			8.0				
1102	Differential Assy	Replace			8.0				
		Repair			8.0				
	Planetary Drive	Replace			4.0				
		Repair			4.0				
12	BRAKES								
1201	Parking Brake Assy	Adjust		0.5				1	
		Replace		3.0					
		Repair		'3.0					
1202	Service Brakes	Adjust		1.0				1	
		Replace		4.0					
		Repair		4.0					

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APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
1204	Master Cylinder	Service	0.5					1	
		Replace		2.0					
		Repair			1.0				
	Wheel Cylinders	Replace		2.0					
		Repair			0.5				
	Lines and Fittings	Replace		2.0					
		Repair		1.0					
13	WHEELS								
1311	Wheel Assembly	Replace		1.5				1	
	Hubs, Bearings, & Seals	Service		1.0					
		Adjust		1.0					
		Replace		2.0					
1313	Tires	Inspect		0.5				1	
		Replace		2.0					
		Repair		2.0					
14	STEERING								
1401	Steering Wheel	Replace		1.0				1	
1405	Yoke Assembly	Service		1.0				1,2	
		Adjust		2.0					

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C--operator/crew F--direct support D--depot
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APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
		Replace			8.0				
		Repair			8.0				
1407	Steering Control Unit	Replace			2.0			1,2	
		Repair			2.0				
1410	Hydraulic Steering Pump	Replace			2.0				
		Repair			2.0				
		Overhaul				4.0			
1411	Hoses, Lines, and Fittings	Replace			1.0			1,2	
		Repair			1.0				
1412	Hydraulic Steering Cylinders	Service		1.0				1,2	
		Replace			1.5				
		Repair			2.0				
15	FRAME								
1501	Power Unit Frame	Repair			3.0			1,2	
	Roll Frame Assy	Repair			3.0				
18	BODY, HOOD, & COWLING								
1801	Hood and Cowling	Replace		1.0				1,2	
		Repair			2.0				

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O--organizational H--general support

APPENDIX A

MAINTENANCE ALLOCATION CHART

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

(1) GROUP NUMBER	(2) COMPONENT/ ASSEMBLY	(3) MAINTENANCE FUNCTION	(4) MAINTENANCE CATEGORY C	O	F	H	D	(5) TOOLS AND EQPT	(6) REMARKS
1806	Seat Assembly	Replace		1.0				1,2	
		Repair			1.0				
74	EARTH MOVING EQUIPMENT COMPONENTS								
7466	Roll Assembly	Replace			4.0			1,2	
		Repair			4.0				
7470	Roll Scrapers	Service		0.5				1,2	
		Replace		1.5					
		Repair		1.5					

*The subcolumns are as follows:

C--operator/crew F--direct support D--depot

O--organizational H--general support

TOOL AND TEST EQUIPMENT REQUIREMENTS

MAINTENANCE ALLOCATION CHART FOR

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

TOOL OR TEST EQUIPMENT REFERENCE CODE	MAINTENANCE CATEGORY	NOMENCLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER
		Unless otherwise noted, all maintenance functions can be accomplished with the tools contained in the following common two sets.		
1	O, F, H	Shop Equip Contact Maint, TRK MTD (SC 4940-97-CL-E-05)	4940-00-294-9518	T10138
1	O, F, H	Shop Equip Org Repair, Light TRK MTD (SC 4940-97-CL-E04)	4940-00-294-9516	T13152
1	O, F, H	Tool Kit Automotive Maint, Org Maint Common #1 (SC 4910-95-CL-A74)	4910-00-754-0654	W32593
1	O, F, H	Tool Kit Automotive Maint, Org Maint Common #2 (SC 4910-95-CL-A72)	4910-00-754-0650	W32730
1	O, F, H	Tool Kit, Light Weight (SC 5180-90-CL-W26)	5180-00-177-7033	W33004
1	O, F, H	Shop Equip Auto Maint and Repair Org Maint Supp #1 (SC 4910-95-CL-A73)	4910-00-754-0653	W32867
1	O, F, H	Shop Equip Welding Field Maint (SC 3470-95-CL-A08)	3470-00-357-7268	T16714
1	O, F, H	Tool Set, Veh Full Tracked Sugg #2 SC 4940-95-CL-A08	4940-00-754-0743	W65747
2	F, H	Shop Equip Gen Purp Repair Semitrlr MTD (SC 4940-97-CL-E03)	4940-00-287-4894	T10549

TOOL AND TEST EQUIPMENT REQUIREMENTS

MAINTENANCE ALLOCATION CHART FOR

ROLLER, VIBRATORY, SELF-PROPELLED HIGH IMPACT,

SINGLE SMOOTH DRUM (CCE)

TOOL OR TEST EQUIPMENT REFERENCE CODE	MAINTENANCE CATEGORY	NOMENCLATURE	NATIONAL/NATO STOCK NUMBER	TOOL NUMBER
2	F, H	Tool Kit Automotive, Fuel and Elec Sys Repair (SC 4910-95-CL-A50)	4910-00-754-0655	W32456
2	F, H	Tool Kit, Master Mechanic and Equip Maint and Repair (SC 5180-90-CL-E05)	5180-00-699-5273	W45060
2	F, H	Shop Set, Fuel and Elec Sys Field Maint Basic (SC 4910-95-CL-A01)	4910-00-754-0714	T30414
2	F, H	Shop Set, Fuel and Elec Sys Field Maint Basic Sup #2 (SC 4910-95-CL-A65)	4910-00-390-7775	T30688
2	F, H	Shop Equip Machine Shop, Field Maint Basic (SC 3470-95-CL-A02)	3470-00-754-0708	T15644
2	F, H	Measuring and Lay Out Tool Set, Mach (SC 5280-95-CL-A02)	5280-00-511-1950	W44512
2	F, H	Tool Kit Body and Fender Repair	5180-00-754-0643	W33689
3	F, H	Wrench Set Socket, 3/4" Drive Hex Type	5310-00-754-0743	W65747
4	O, F, H	Wrench Torque, 3/4" Drive 500 lb Cap	5120-00-542-5577	Y84966
5	O, F, H	Multimeter	6625-00-999-7465	M80242

APPENDIX B

BASIC ISSUE ITEMS LIST

NOMENCLATURE:
MANUFACTURER:
SERIAL NUMBER RANGE:

DATE:

(1) MFR PART NO.	(2) MFR FED CODE	(3) DESCRIPTION	(4) UNIT OF ISSUE	(5) QUANTITY FURNISHED W/EQUIP

ITEMS TROOP INSTALLED OR AUTHORIZED LIST

(1) SMR CODE	(2) NATIONAL STOCK NUMBER	(3) DESCRIPTION REF NO & MFR CODE	USABLE ON CODE	(4) UNIT OF MEAS	(5) QTY AUTH

NOTE

The following items are overpacked with the roller.

	7520-00-559-9618	Case, Cotton Duck: MIL-B-11743 (81349)		EA	1
	7510-00-889-3494	Log Book Binder: MIL-B-43064		EA	1

NOTE

The following items are authorized but not issued with the roller.

	4210-00-889-2221	Extinguisher, Fire Dry Chemical		EA	1
	4930-00-277-9525	Grease Gun, Hand		EA	1
	4930-00-204-2550	Adapter, Grease Gun Coupling, Rigid		EA	1
	4930-00-288-1511	Adapter, Grease Gun Coupling, Flex		EA	1

APPENDIX C

MAINTENANCE AND OPERATING SUPPLY LIST

NOMENCLATURE: Roller, Vibratory, Self-Propelled, Single, Smooth Drum (CCE) MAKE: TAMPO MODEL: RS-28

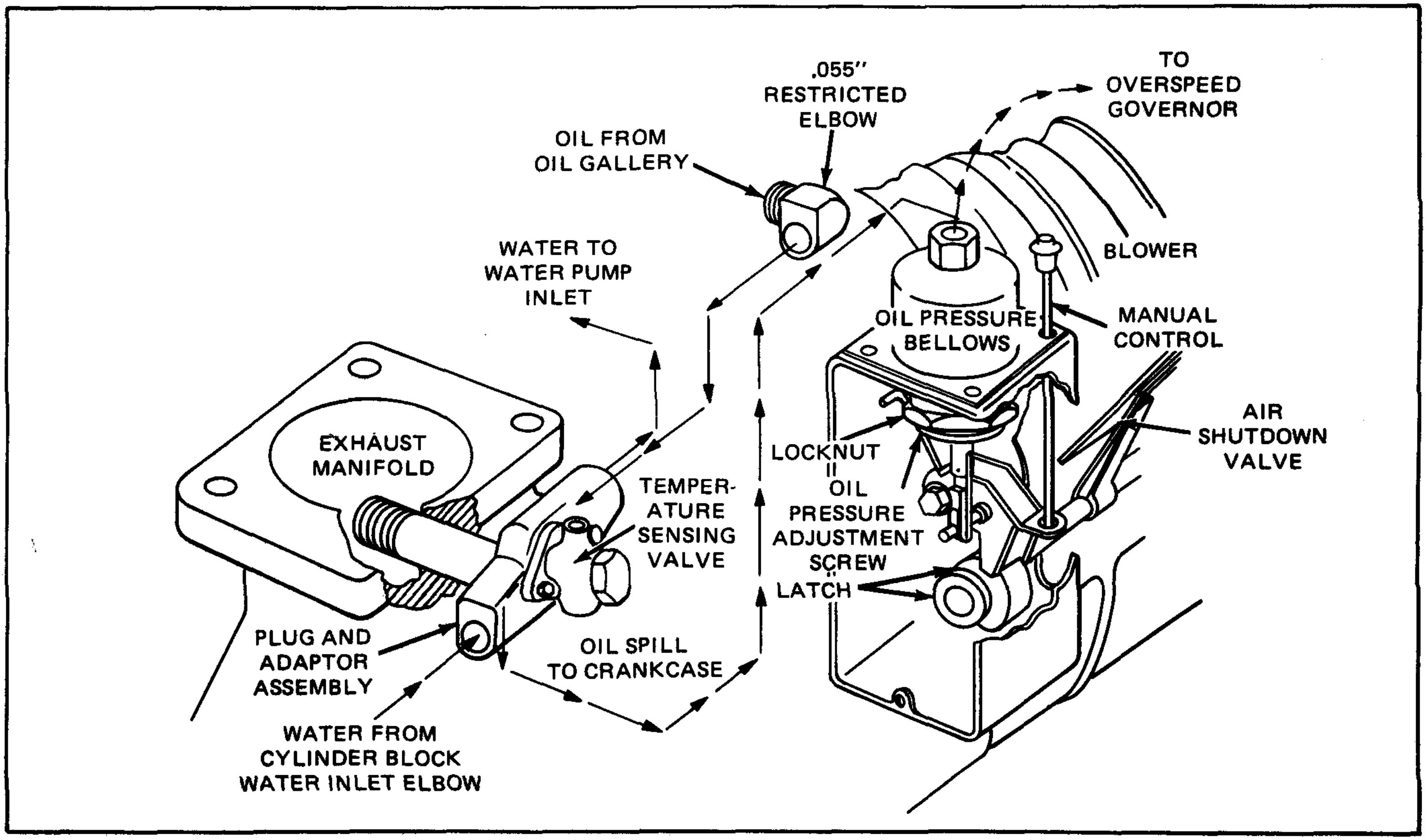
MFR PART NO: NSN: 3895-01-012-8875 SERIAL NO. RANGE: TO DATE: FEB 79

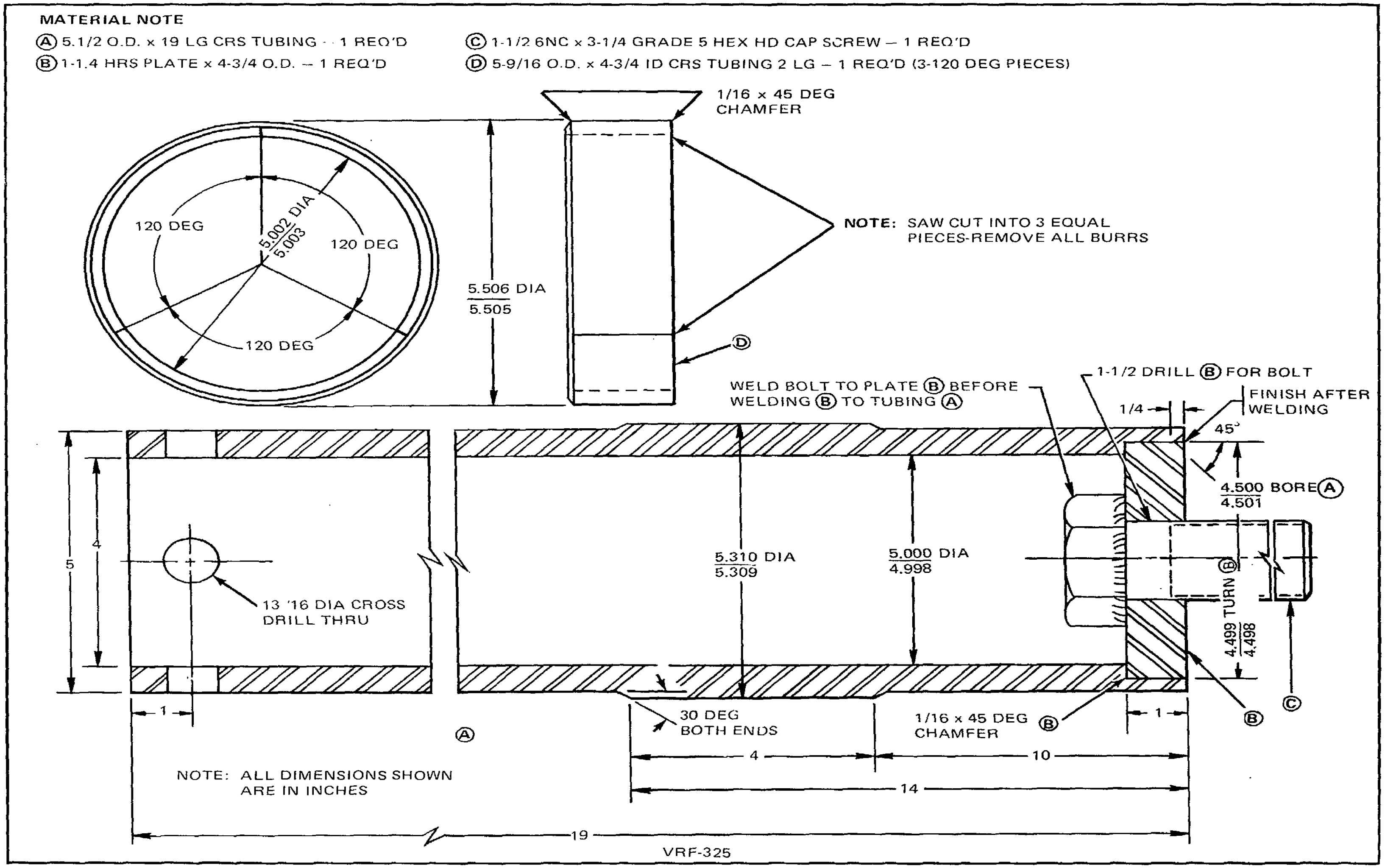
(1) COMPONENT APPLICATION	(2) MFR PART NO. OR NAT'L STOCK NO.	(3) DESCRIPTION	(4) QTY REQ F/INITIAL OPN	(5) QTY REQ F/8 HRS OPN	(6) NOTES
Drive Axle Differential	9150-01-035-5395	Lubricating Oil GO 85w/140 MIL-L-2105C	8 qt		5 gal
Drive Axle Planetary	9150-01-035-5395	Lubricating Oil, GO 85w/140 MIL-L-2105C	4 qt		5 gal
Eccentric Shaft Bearings	9150-01-035-5392	Lubricating Oil, GO 80w/90 MIL-L-2105C	14 qt		1 qt
General Applica-tion	9150-00-190-0905	GAA Grease, MIL-G-10924	A/R		
Cooling System	6850-00-181-7933	Anti-Freeze Permanent	25 qt		50-50 solution

APPENDIX D

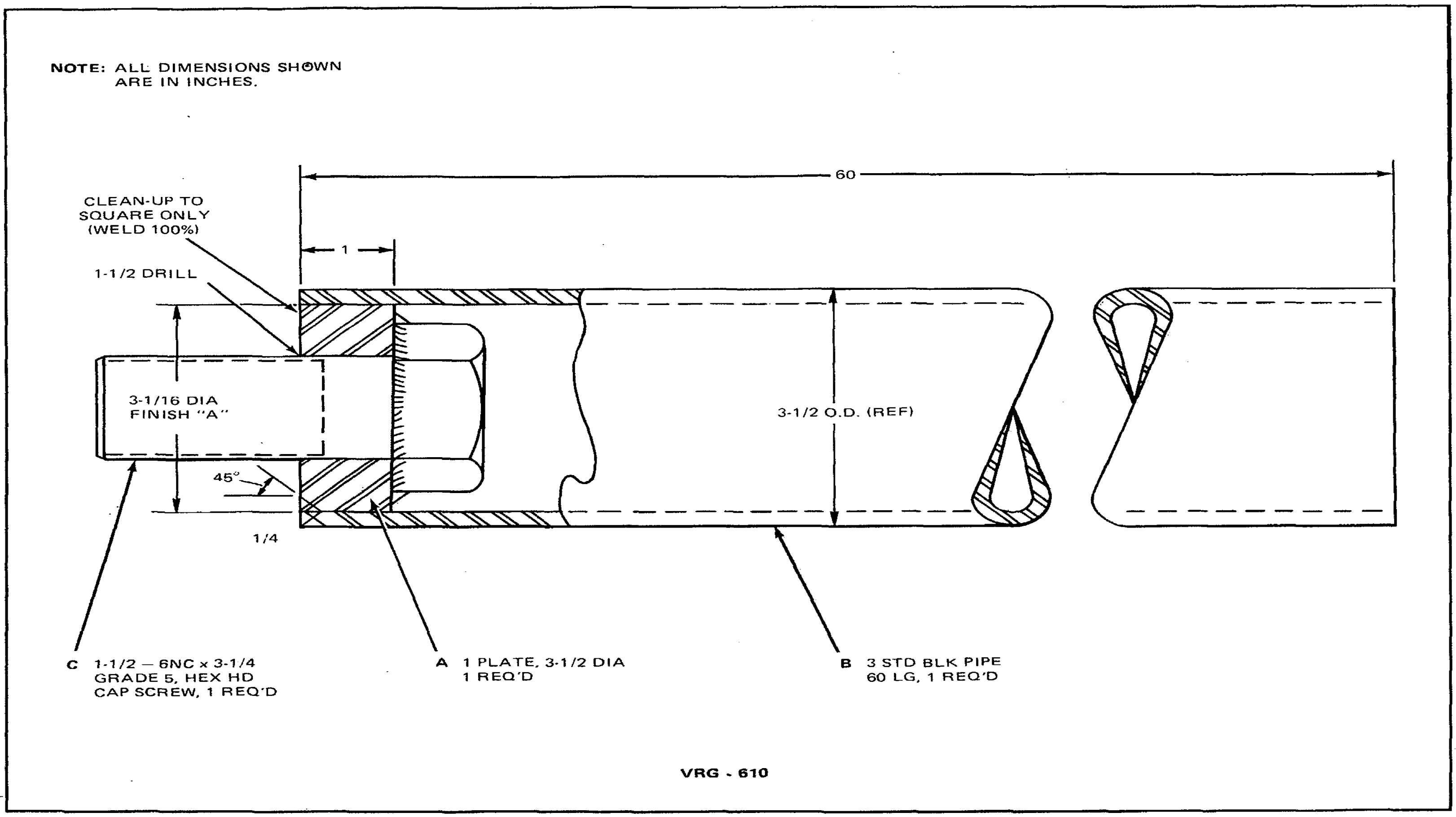
FABRICATED TOOLS

ECCENTRIC SHAFT BEARING REMOVAL

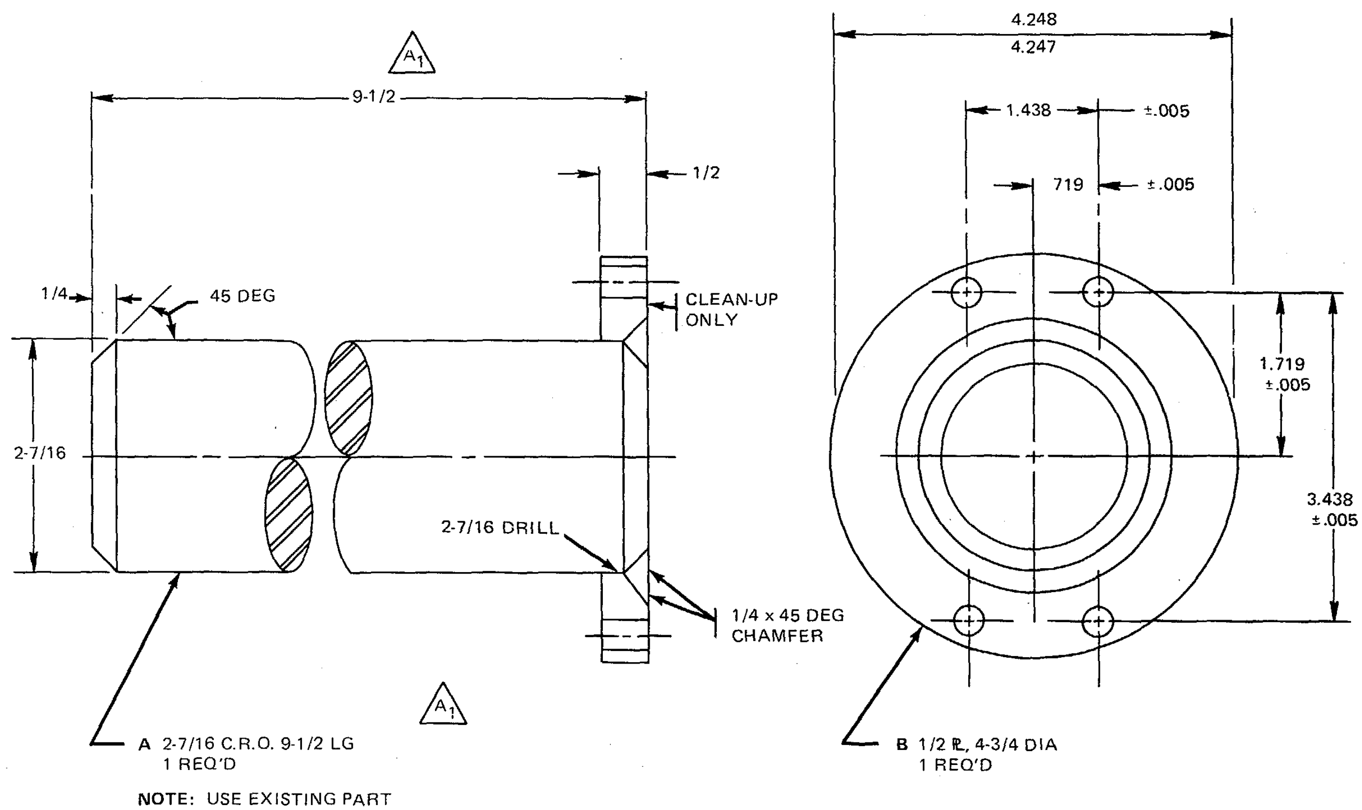




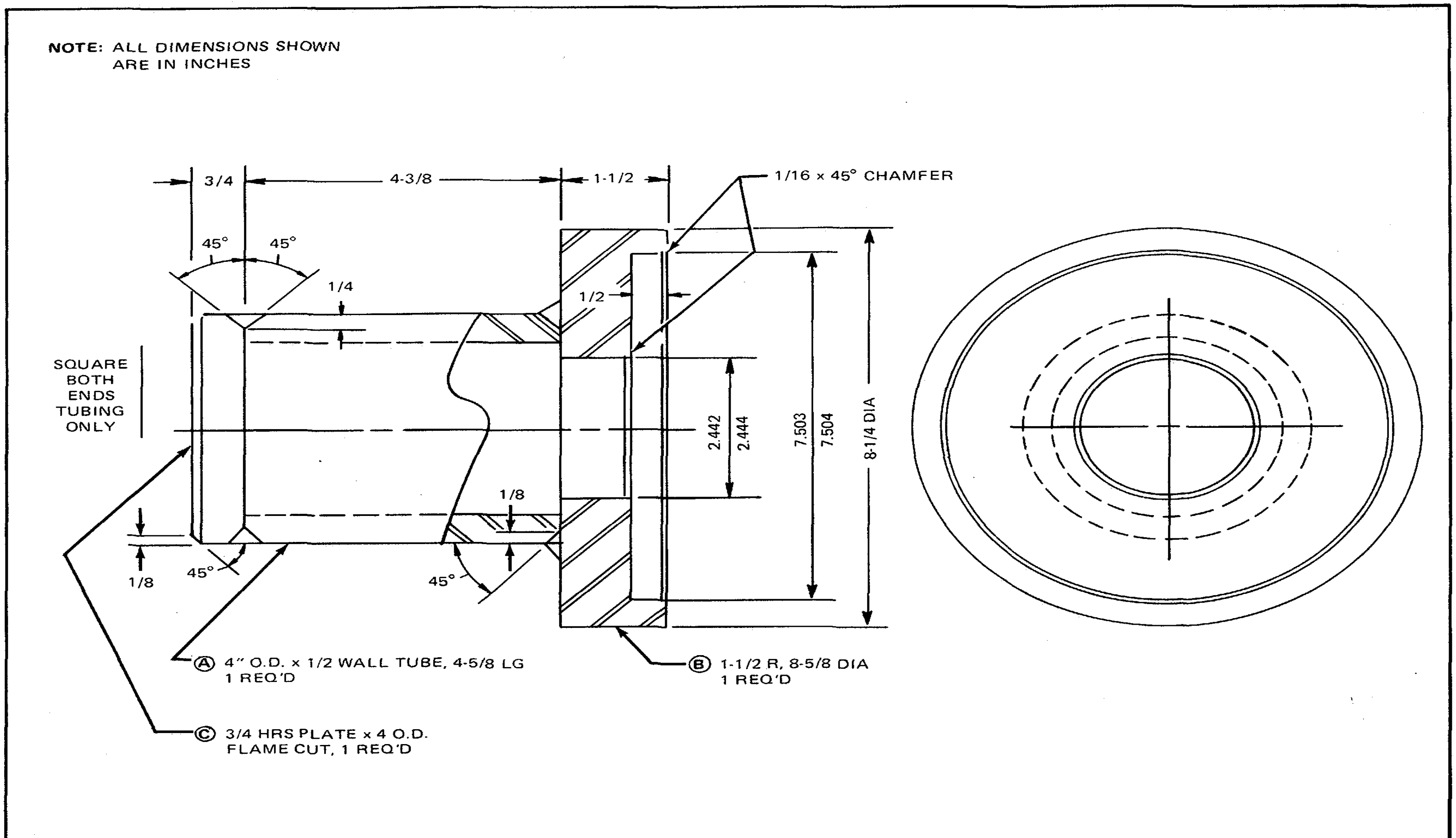
MATERIAL NOTE
Ⓐ 5.1/2 O.D. x 19 LG CRS TUBING - 1 REQ'D
Ⓑ 1-1.4 HRS PLATE x 4-3/4 O.D. – 1 REQ'D
Ⓒ 1-1/2 6NC x 3-1/4 GRADE 5 HEX HD CAP SCREW – 1 REQ'D
Ⓓ 5-9/16 O.D. x 4-3/4 ID CRS TUBING 2 LG – 1 REQ'D (3-120 DEG PIECES)
1/16 x 45 DEG CHAMFER
120 DEG
5.002 / 5.003 DIA
120 DEG
120 DEG
5.506 / 5.505 DIA
NOTE: SAW CUT INTO 3 EQUAL PIECES-REMOVE ALL BURRS
Ⓓ
WELD BOLT TO PLATE Ⓑ BEFORE WELDING Ⓑ TO TUBING Ⓐ
1-1/2 DRILL Ⓑ FOR BOLT
FINISH AFTER WELDING
1/4
45°
4.500 / 4.501 BORE Ⓐ
5
4
13/16 DIA CROSS DRILL THRU
5.310 / 5.309 DIA
5.000 / 4.998 DIA
4.499 / 4.498 TURN Ⓑ
Ⓒ
Ⓑ
1
Ⓐ
30 DEG BOTH ENDS
1/16 x 45 DEG CHAMFER Ⓑ
1
4
10
14
NOTE: ALL DIMENSIONS SHOWN ARE IN INCHES
19
VRF-325


NOTE: ALL DIMENSIONS SHOWN ARE IN INCHES.
60
1
CLEAN-UP TO SQUARE ONLY (WELD 100%)
1-1/2 DRILL
3-1/16 DIA FINISH "A"
45°
1/4
3-1/2 O.D. (REF)
C 1-1/2 — 6NC x 3-1/4 GRADE 5, HEX HD CAP SCREW, 1 REQ'D
A 1 PLATE, 3-1/2 DIA 1 REQ'D
B 3 STD BLK PIPE 60 LG, 1 REQ'D
VRG - 610

NOTE: ALL DIMENSIONS SHOWN
ARE IN INCHES



VRF-1039-A


NOTE: ALL DIMENSIONS SHOWN
ARE IN INCHES
3/4
4-3/8
1-1/2
1/16 x 45° CHAMFER
45°
45°
1/4
1/2
SQUARE
BOTH
ENDS
TUBING
ONLY
2.442
2.444
7.503
7.504
8-1/4 DIA
1/8
1/8
45°
45°
Ⓐ 4" O.D. x 1/2 WALL TUBE, 4-5/8 LG
1 REQ'D
Ⓑ 1-1/2 R, 8-5/8 DIA
1 REQ'D
Ⓒ 3/4 HRS PLATE x 4 O.D.
FLAME CUT, 1 REQ'D

VRF-1039-B

INDEX

INDEX (Continued)

INDEX (Continued)

REPAIR PARTS LIST
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REPAIR PARTS LIST
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By Order of the Secretary of the Army:

JOHN A. WICKHAM, JR.
General, United States Army
Chief of Staff

Official:

DONALD J. DELANDRO
Brigadier General, United States Army
The Adjutant General

Distribution:

To be distributed in accordance with DA Form 12-25B, Operator; Organizational; Direct and General Support Maintenance requirements for Roller, Vibratory Self-Propelled.

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P.S.--IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS.

TEAR ALONG PERFORATED LINE

The Metric System and Equivalents

Linear Measure

1 centimeter = 10 millimeters = .39 inch
1 decimeter = 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

Weights

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = .035 ounce
1 dekagram = 10 grams = .35 ounce
1 hectogram = 10 dekagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

Liquid Measure

1 centiliter = 10 milliters = .34 fl. ounce
1 deciliter = 10 centiliters = 3.38 fl. ounces
1 liter = 10 deciliters = 33.81 fl. ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 26.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

Square Measure

1 sq. centimeter = 100 sq. millimeters = .155 sq. inch
1 sq. decimeter = 100 sq. centimeters = 15.5 sq. inches
1 sq. meter (centare) = 100 sq. decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 100 sq. meters = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

Cubic Measure

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. centimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

Approximate Conversion Factors

To change	*To*	*Multiply by*	*To change*	*To*	*Multiply by*
inches	centimeters	2.540	ounce-inches	newton-meters	.007062
feet	meters	.305	centimeters	inches	.394
yards	meters	.914	meters	feet	3.280
miles	kilometers	1.609	meters	yards	1.094
square inches	square centimeters	6.451	kilometers	miles	.621
square feet	square meters	.093	square centimeters	square inches	.155
square yards	square meters	.836	square meters	square feet	10.764
square miles	square kilometers	2.590	square meters	square yards	1.196
acres	square hectometers	.405	square kilometers	square miles	.386
cubic feet	cubic meters	.028	square hectometers	acres	2.471
cubic yards	cubic meters	.765	cubic meters	cubic feet	35.315
fluid ounces	milliliters	29,573	cubic meters	cubic yards	1.308
pints	liters	.473	milliliters	fluid ounces	.034
quarts	liters	.946	liters	pints	2.113
gallons	liters	3.785	liters	quarts	1.057
ounces	grams	28.349	liters	gallons	.264
pounds	kilograms	.454	grams	ounces	.035
short tons	metric tons	.907	kilograms	pounds	2.205
pound-feet	newton-meters	1.356	metric tons	short tons	1.102
pound-inches	newton-meters	.11296			

Temperature (Exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

PIN: 056865-000